# An examination of the effects on learning seen in children afforded the opportunity to control the order of repetitions for three novel spatiotemporal sequences

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## DEDICATION

I would like to thank those who supported me throughout my schooling thus far and provided me with encouragement to continue. Specifically I would like to thank my family who listened patiently to me talk about my research and provided encouragement throughout.

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**ABSTRACT**

Children were afforded the opportunity to control the order of repetitions for three novel spatiotemporal sequences. The following was predicted: a) children and adults in the self-regulated (SELF) groups would produce faster movement (MT) and reaction times (RT) and greater recall success (RS) during retention compared to the age-matched yoked (YOKE) groups; b) children would choose to switch sequences less often than adults; c) adults would produce faster MT and RT and greater RS than the children during acquisition and retention, independent of experimental group. During acquisition, no effects were seen for RS, however for MT and RT there was a main effect for age as well as block. During retention a main effect for practice condition was seen for RS and failed to reach statistical significance for MT and RT, thus partially supporting our first and second hypotheses. The third hypothesis was not supported.

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# CHAPTER 1: REVIEW OF LITERATURE

## 1.1 Motor learning and practice variables

Motor learning is defined as a set of internal processes associated with practice, leading to a relatively permanent change in one's ability to perform a motor skill (Schmidt & Lee, 2005). Motor performance is defined as an observable motor behaviour, such as reaction time, movement time, performance kinematics or accuracy (Magill, 2004). An example of motor performance is a golfer's putt stopping one foot from the target hole. Unlike motor performance, motor learning can not be directly measured, but must be inferred through measurement of relatively permanent changes in performance of a motor skill. Learning is inferred from performance during a retention test. A retention test occurs following practice of the skill and a period of time where the skill has not been practiced (Magill, 2004).The length and timing of the break is also important. Usually two retention tests are conducted during an experiment. The first retention test is performed on the same day as acquisition and the second after a period of time that includes sleep. Sleep is important for retention of a skill (Walker, Brakefield, Morgan, Hobson & Stickgold 2002). An example of measuring retention would be if a learner took 2000 milliseconds to complete a key pressing sequence at the beginning of practice and then by the end of the practice session took 1500 milliseconds to complete the same sequence, they would have shown an improvement in motor performance, particularly time to completion. If the learner attempted the same task the next day and took only 1500 milliseconds to complete the sequence, then it can be inferred that motor learning has taken place because the improvement of 500 milliseconds was due to practice and, since it was maintained for the retention test, is relatively permanent. Another way of measuring mastery of the task is a transfer test. A transfer test requires the learner to perform the task they had been practicing, in a different context or to perform a novel variation of the task. For example if the learner was completing a key-pressing task, a transfer test would have them complete it with the other hand or with a different timing goal.

Guadagnoli & Lee (2004) discuss the concept of an optimal challenge point for learning. The optimal point is different for each learner and depends on the amount of information the learner is receiving and is able to interpret from a given performance. Too much information received by the learner can be detrimental to learning, as can too little information. As the amount of information provided to the learner increases, so does the complexity of the task. Using the golf putt as an example, both the golfer themselves (novice or experienced) and their interaction with the environment produce information. The putt on a flat green, with few distractions, produces less information from external sources as compared to a more difficult putt. When the green is undulated, more information needs to be processed about the green in order to make a successful putt. The people nearby are also providing more sensory information, both visual and auditory. The more difficult putt may provide the experienced golfer with the right amount of challenge, whereas a novice golfer may be overwhelmed with all of the information provided. Therefore, the optimal challenge point is also based on the skill level of the person performing the task. Optimal challenge points are individual to the learner and can change over time and with practice. For example, the novice golfer may improve over time and be able to interpret more information successfully. Therefore an individual strategy for a learner's specific, individual needs is beneficial.

There are many practice variables involved in performing a given motor skill. Manipulation of these variables can influence the effectiveness of the learning condition. Such practice variables include the scheduling of practice as well as the type and frequency of feedback.

The ways in which practice should be scheduled in order to maximize the learning of skills are of particular interest. In most situations, a practice session will incorporate more than one skill or more than one version of a skill. The repetition order of when each of these skills is practiced can affect learning outcomes. The two most commonly studied schedules of practice repetition variability are blocked practice and random practice. Blocked practice is a practice sequence, uninterrupted by any other task, where all the trials of one task are completed before performing the next task (Schmidt & Lee, 2005). For example, if there were three key-pressing sequences to learn, the learner would practice sequence A 10 times, then practice sequence B 10 times and then practice sequence C 10 times. Random practice is a practice sequence where the tasks being practiced are randomly ordered across the trials, where no more than two trials of the same task are practiced together. More than one skill is practiced within a block of practice trials (Schmidt & Lee, 2005). For example, in each 10 trial practice block, sequences A, B and C would be practiced at least three times each. Each sequence is practiced the same amount of times, but they are interdispersed within the practice blocks.

An important study that led the way for current practice organization studies was conducted by Shea and Morgan (1979). The authors designed a barrier knock down task utilizing blocked and random practice in order to examine the effects of contextual interference (CI). The concept of CI was first examined in verbal learning (Battig 1972; Hiew, 1977 as cited in Shea & Morgan 1979). CI is defined as the interference caused by performing different variations of a skill in a practice context (Magill, 2004). The level of CI can be manipulated by how a given practice session is scheduled. A blocked practice schedule would have relatively little CI compared to an entirely random practice schedule, whereas other types of practice, such as serial practice, (e.g. A then B then C) fit somewhere in between on a scale of CI (Shea & Morgan 1979). A CI effect is seen when performers under a high CI condition, such as random practice, perform better on retention and/or transfer tests than those in a lower CI condition, such as blocked practice. Shea and Morgan's (1979) study showed that the CI effect can be generalized to a motor learning context. In their study, those who completed acquisition under a blocked practice schedule, and were later given a retention test under a random schedule performed with much slower reaction times, movement times and total times compared to the groups that practiced under blocked acquisition to blocked retention, random acquisition to blocked retention and random acquisition to random retention. There are two complimentary explanations of why the CI effect is seen. The elaboration benefit explanation and the action plan reconstruction view are both discussed in a review of the CI effect by Magill and Hall (1990). The elaboration benefit explanation describes multiple encoding processes and the opportunity to compare them as a benefit for retention as there are more retrieval routes available during retention (Magill & Hall, 1990). The action plan reconstruction view discusses the increase of effortful processing during random practice, due to forgetting some of the information between trials of a given task as an explanation of the CI effect (Magill & Hall, 1990).

Blocked practice has been shown to be advantageous for learning a motor skill when the skill level of the learner is very low or if the task is very difficult. In those instances, there is enough information demand on the cognitive processes of the learner that the positive effects of random practice are no longer seen (Albaret & Thon, 1998). Random practice has been shown to produce more error during the acquisition of a skill, compared to blocked practice but, a retention test reveals that it enhances learning because those who practiced under a random schedule outperform those who practiced under a blocked schedule. The proposed mechanism of this learning is the cognitive effort invested in the task, which is greater when a random practice schedule is followed. Random practice is most beneficial when the learner has a general idea of the movement or if it is a relatively easy task. Random practice increases the functional task difficulty by requiring more information to be interpreted whereas blocked practice has relatively less information to be interpreted (Guadagnoli & Lee, 2004). What these two schedules have in common is that the schedule itself is determined by the investigator and therefore not individualized to the performer's unique learning needs. The majority of motor learning literature involves practice conditions that are investigator defined, which compared to when the learner is involved, provides less motivation, responsibility and opportunity to deeply process information by making decisions (Chiviacowsky & Wulf, 2002).

**1.2 Self-regulation**

Lee, Swinnen, & Serrien (1994) discuss cognitive effort as an important influence on learning. They define cognitive effort as the mental processes involved in making decisions. Zimmerman (1985) describes someone as a self-regulator when they actively participate metacognitively, motivationally and behaviourally in their own learning process. It is the "active" part of this definition that is most important in determining how well the participant will learn.

The benefits of self-regulated practice contexts are generally viewed as robust across many conditions and tasks when examining a healthy adult population. The benefits of self-regulation of practice variables have been evident in the contexts of augmented feedback, observational learning, use of assistive devices and repetition scheduling as compared to investigator-regulated schedules or schedules determined by another participant ( e.g. yoked) (Chiviacowsky and Wulf, 2002; Chiviacowsky & Wulf, 2005; Chiviacowsky, Wulf, Medeiros, Kaefer & Tani, 2008; Chiviacowsky, Wulf, Medeiros, Kaefer & Wally, 2008; Hartman, 2007; Janelle, Kim & Singer,1995; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Keetch & Lee, 2007; Titzer, Shea, & Romack, 1993; Wrisberg & Pein, 2002; Wu & Magill, 2004; Wu, 2007; Wulf, Clauss, Shea, & Whitacre, 2001; Wulf, Raupach, & Pfeiffer, 2003;Wulf & Toole, 1999). In a yoked practice condition, each participant is matched to a participant in the self-regulated group, whereby the exact same schedule is used for a participant in the yoked group, without the choice.

The first motor learning practice context in which self-regulation of a practice variable was incorporated was the provision of feedback. Janelle, Kim & Singer (1995) used an underhand ball toss task to examine the benefits of a self-regulated feedback schedule. The feedback provided was indicative of the performance of the learner, which is called knowledge of performance (KP). Along with the group that self-regulated KP, Janelle and colleagues included a summary KP group that was provided KP about a group of trials, a 50% KP group that was provided KP on 50% of the trials, a no KP group and a yoked KP group. The yoked group received KP in an identical schedule to a counterpart in the self-regulated practice variable group. The only difference between the two groups was that the group which self-regulated the practice variable was given a choice. The yoked group is significant because it eliminated the possibility that the greater retention effects were due to the frequency of KP. Any differences seen between the two groups could most likely be attributed to the actual decision making involved in the self-regulated condition. The participants in the group which self- regulated KP performed significantly better on retention tests than those in the researcher-determined and yoked KP groups. Those in the group which self-regulated KP asked for KP less often as the practice trials progressed, resulting in a faded KP schedule. Janelle et al. (1995) concluded that those in the group which self-regulated KP had processed information more efficiently.

Janelle, Barba, Frehlich, Tennant, & Cauraugh (1997) conducted a similar study, which also examined self-regulation of KP. The task examined was throwing a ball. The groups utilized were a knowledge of results (KR) group which were provided only with information about the outcome of the task, a summary KP group, a group which self-regulated KP, and a yoked group. The participants in the group which self-regulated KP performed with greater accuracy and form during a retention test than those in the yoked and summary KP groups. The authors suggested that the benefits observed in the group which self-regulated KP could be due to the influences of motivation on cognitive processes, learner involvement and increased learner responsibility.

Chiviacowsky & Wulf (2002) found similar benefits to a self-regulated KR schedule as compared to a yoked group. Those in the group which self-regulated KR performed with lower absolute error scores during a transfer test for a relative timing, key pressing task. Chiviacowsky & Wulf (2002) hypothesized that those in the group which self-regulated KR asked for feedback when they needed it, and therefore could use feedback more effectively. Those in the yoked group were not given the opportunity to individualize their feedback schedule. In addition, the participants in the group which self-regulated KR completed questionnaires which provided insight into when they did or did not ask for feedback and why they made those decisions. Those in the yoked group were asked if the feedback was provided when it was needed. Those in the group which self-regulated KR chose to receive feedback most often on trials they perceived as good (e.g. lower absolute timing errors.) This was confirmed to be true by lower absolute timing errors on trials where feedback was requested compared to trials where feedback was not requested. Those in the yoked group would have also liked to receive feedback on perceived good trials, but did not. Information from the questionnaires indicated the use of a confirmation of accuracy strategy by those in the group that self-regulated KR. The information from the questionnaires also indicated that those in the yoked group would have adopted a similar strategy if given the opportunity.

Chiviacowsky & Wulf (2005) expanded upon this experiment by examining differences between the participant choosing whether or not to receive feedback about a specific trial before or after the completion of that trial. They examined relative timing error during a key pressing task involving specific goal times. The group that chose to receive feedback after completing the trial performed with less relative timing error on a retention test compared to the group that chose whether or not to receive feedback before the trial was completed and with significantly less relative timing error on a transfer task. Chiviacowsky & Wulf (2005) concluded that investigators giving participants the opportunity to introspect on their performance is an essential factor in facilitating the decision making of participants in a self-regulated practice context.

Use of assistive devices, such as ski poles, has also been examined in the context of self-regulation. Wulf & Toole (1999) provided a group with the opportunity to self-regulate the requests for the use of ski poles during acquisition of a ski slalom movement task. They also included a yoked group and a group that did not have the opportunity to use the ski poles. No differences in performance were seen between the group which self-regulated the use of the ski poles and the yoked group during acquisition, but the group which self-regulated the use of ski poles performed significantly better than the yoked group during the retention test. A questionnaire was also incorporated into the acquisition portion of the study, revealing that there were no differences in fear of falling between the group which self-regulated the use of ski poles and yoked groups. Questionnaire data also indicated that those in the yoked group overestimated how well they would reproduce the movement during the retention test. Wulf & Toole (1999) concluded that those in the group which self-regulated the use of ski poles were able to try out different strategies and chose conditions that were beneficial to learning.

Wulf, Clauss, Shea & Whitacre (2001) expanded upon the work of Wulf and Toole (1999) by having participants practice in a dyad (e.g. in partners) of one participant who self-regulated the use of ski poles and one participant that followed a yoked schedule. Wulf and colleagues (2001) also used a slalom ski amplitude task. The participant who self-regulated the use of the ski poles was given the opportunity to choose when they would like to use the ski poles during two days of acquisition. The participant in the yoked practice condition would also use the poles on the same trials as the participant that self-regulated the use of the ski poles. The participant in the yoked practice condition was able to view the participant that self-regulated the use of the ski poles prior to completing the trial themselves. According to the authors, this practice condition may have been beneficial to the learning of visible measurements, such as amplitude and frequency. Though there were no differences in amplitude and frequency between the group which self-regulated the use of ski poles and the yoked groups, the group which self-regulated the use of ski poles performed the task more efficiently as evidenced by later relative onsets of force. Also of interest is that those in the group which self-regulated the use of ski poles chose a similar fading schedule to those in Janelle et al (1995).

Hartman (2007) also utilized a group which self-regulated the choice of when to use ski poles during acquisition. The task Hartman (2007) examined was balancing on a stabilometer. The group which self- regulated the choice of when to use ski poles maintained balance on the stabilometer during retention significantly longer than those in the yoked group. This study generalized the benefits of self-regulation of an assistive device to a more static continuous task.

Self-regulated scheduling of viewing a skilled model for a badminton serve was examined by Wrisberg & Pein (2002), who showed similar retention scores between the group which self-regulated the scheduling of viewing of a skilled model and the group who viewed the model on 100% of the acquisition trials. Both of those groups also performed better than a group who had not seen the demonstration at all. The authors discussed that this could have been due to cognitive processes involved in self-regulation. Wrisberg & Pein (2002) did not incorporate a yoked group, which would differentiate between reduced frequency and self-regulation processes. Similar to Janelle et al (1995) and Hartman (2007), Wrisberg & Pein (2002) found that participants in the group which self-regulated the scheduling of viewing a skilled model asked to view the model in a faded type schedule during acquisition.

However, a study by Wulf, Raupach & Pfeiffer (2003) included a yoked group. They examined participants learning a basketball jump shot who were provided the opportunity to self-regulate viewing of a skilled model. Once again, the self-regulated group demonstrated greater movement form and performed more accurately than the yoked group.

The first study examining choice in practice scheduling was conducted by Titzer, Shea & Romack (1993). Experimental groups completed a computer simulated barrier knock down task with three distinct movement patterns. The experimental groups followed either a blocked, random or self-regulated practice schedule. Movement time, reaction time, and error were measured. During the acquisition phase, those following both blocked and self-regulated practice schedules showed reaction times significantly superior to the random practice schedule. During the first retention test (immediately after the acquisition phase) the group that self-regulated their practice schedules showed significantly faster overall movement times compared to the blocked and random groups as well as reaction times significantly faster than the blocked group. During a second retention test, conducted 24 hours after the first, both the group that self-regulated their practice schedules and the random group, showed significantly fewer errors than the blocked group.

Though this study showed that the group that self-regulated their practice schedules had similar results to the blocked practice group in acquisition, and to the random practice group in retention, it was unclear whether the positive results were due to cognitive processes required to make a choice or due to the semi-random nature of the schedule chosen (similar to the random condition). In order to make this distinction between the cognitive processes utilized in self-regulation and the learning effects associated with random practice schedules, a yoked group would be required.

More recently, Wu & Magill (2004) examined self-regulation of practice repetition schedules for three distances of golf putting. The authors included a yoked group and therefore built upon the findings of Titzer and colleagues. The results indicated that the group that self-regulated their practice schedules performed better than the yoked group for the retention tests five minutes and 24 hours after the last acquisition trial.

In a follow-up study utilizing a three-key relative timing task, Wu (2007) also found that the group that self-regulated their practice schedules showed superior performance on both a five minute and a 24 hour retention test as compared to the yoked group. Interestingly, the group that self-regulated their practice schedules chose a blocked-type repetition schedule near the beginning of the acquisition trials and then progressed to a more randomized type practice schedule towards the end of acquisition. A second follow up study using the same key pressing task, incorporated a self-before group who determined their entire practice schedule prior to completing any trials and a self group which chose their own practice schedule on a trial by trial basis. The self-before group was instructed to write out a practice schedule for the three tasks prior to commencing with any of the acquisition trials and then follow it during acquisition, while the self group chose their schedule on a trial by trial basis. The self group was also given KR on each trial which is an extra source of information. On the 24-hour transfer test, the self group performed better than the self-before group. The self group was able to introspect on their performance during acquisition, thus influencing their decision of practice repetition scheduling. The self group was also able to change strategies mid-practice, taking into consideration the effectiveness of their current strategy. The self-before group were not afforded these opportunities, based on their inability to use task performance information to modify their strategies. These results show the importance of being able to assess current performance and strategies and adapt them if necessary while learning a motor task.

Keetch & Lee (2007) found the benefit of self-regulated practice schedules extended across both simple and complex tasks. They used a mouse directed task that required the participant to follow a specified pattern on a computer screen. The simple tasks required the participants to use their dominant hand and had a less complex sequence of left and right mouse clicks than the complex tasks which required the participants to use their non-dominant hand and involved a more complex sequence of mouse clicks. Keetch & Lee (2007) found no particular benefit for self-regulation over blocked, random, or yoked groups upon completion of acquisition; however, the self-regulated group demonstrated the most improved performance in a retention test, for both the simple and the difficult patterns.

In each of these practice variables the learner is making a choice. In the cases of augmented feedback, observational learning and use of an assistive device, the choice has two possible answers: Yes, I do want (feedback, to view the model, use of the assistive device) or No, I do not want (feedback, to view the model, use of the assistive device). In the case of repetition scheduling the choice is comparatively more complex as commonly there are three tasks to choose from. The nature of the decision being made may differentiate repetition scheduling from other self-regulated practice contexts.

Wulf (2007) summarized the explanations provided by several authors for the benefits of self-regulated practice conditions. The most common explanations for these benefits are: 1) the learners are taking charge of their own learning process and therefore may be more motivated and may show increased effort in practice (Ferarri,1996; McCombs,1989 & Watkins 1984, as cited by Wulf 2007), 2) practice conditions may be better suited to the individual's needs compared to predetermined practice conditions (Chiviacowsky & Wulf, 2002; Wulf & Toole 1999 & Hartman, 2007 as cited by Wulf 2007.)

In summary, self-regulation research to date has determined that allowing the learner to have control over a portion of the learning environment (practice repetition, feedback scheduling, use of assistive devices or viewing of a skilled model) can enhance retention of several types of motor skills such as: barrier knock down tasks (Titzer et al., 1993), mouse directed aiming tasks (Keetch & Lee, 2007), key pressing sequences (Chiviacowsky et al., 2002; Wu, 2007), golf putting (Wu & Magill, 2004), underhand throws (Janelle et al., 1995; Janelle et al., 1997), slalom ski movements (Wulf et al, 2001; Wulf & Toole, 1999), badminton serves (Wrisberg & Pein, 2002), and basketball free throws (Wulf et al.,2003). These tasks cover several classifications of motor tasks including discrete, such as an underhand throw (Janelle et al., 1995; Janelle et al., 1997) serial, such as key pressing sequences (Wu, 2007) and continuous, such as slalom ski movements (Wulf et al, 2001; Wulf & Toole, 1999.) If the participant is afforded the opportunity to introspect on their performance and is able to individualize an aspect of practice accordingly, motor learning is improved significantly compared to if they were not afforded the opportunity (e.g. yoked condition). The benefit of self-regulation in motor learning tasks for young adults has been well established. However, self-regulation of motor task practice variables has only very recently been examined in pediatric populations.

### 1.3 Children and Motor Tasks

A study by Thomas, Yan & Stelmach (2000), found differences in how movement substructures change with practice between children and adults during a rapid aiming task. The aiming task was divided into two parts, or submovements: a) the ballistic, controlled part of the movement (primary submovement) and b) the corrective adjustments (secondary submovement). The overall smoothness of the movement was also measured. After practice, during retention tests, both adults and children increased the primary submovement, with the increase being much larger in the children (25–30%) than in the adults (10 %). This means that the participants were making a more accurate movement towards the target. The smoothness of the movement also increased for both groups, but more so in the children. These results suggest that motor learning factors, such as practice can have an even greater effect in children than adults, and supports the need for more investigation of factors that effect motor learning in children.

Pollock & Lee (1997) examined seven-year-old children and university-aged adults completing a ballistic aiming task under blocked or random practice. The blocked group adults performed best during acquisition, while there were no differences between the seven-year-old groups. Retention and transfer tests were performed better by the random groups for both age conditions. These results suggest that children and adults learned equally well in a random practice context.

Practice scheduling and the interaction of complexity, both in the scheduling itself (for example, random versus blocked practice), and in task variations have been examined by numerous researchers with varying results. Jarus & Goverover (1999) studied the effects of blocked, random and combined (blocked practice for the first half of trials and random for the second) practice on retention and transfer for five-year-olds, seven-year-olds and eleven-year-olds completing a bean-bag throwing task. For the group of seven-year-olds, the combined and blocked practice groups showed significant improvement in retention as compared to the random practice group. There were no differences seen between groups for the five-year-olds or the eleven-year-olds in retention or amongst all groups during transfer. These results support the need to further investigate motor learning principles in children as differences in learning were seen between age groups.

Nair & Bunker (2000) examined blocked, random and progressive blocked practice schedules for three field hockey skills (push pass, flick and dribble) in fifth and sixth grade children. The progressive blocked practice group performed significantly better than the blocked group in retention for all three tasks. The results of the random practice group were equal to or less than the progressive blocked group between the three tasks, and the blocked group consistently performed poorest on all three tasks. These results support the idea of an optimal amount of information facilitating learning in children, with too much or too little information hindering the learning process.

Wulf (1991) found that similar to previous studies with adults, children displayed less error in accuracy during a transfer test for a throwing task when practicing under random practice conditions as compared to semi-random (randomized blocks), blocked or constant practice conditions. This supports the idea that random practice conditions can be beneficial for transfer of tasks in children as well as being beneficial in retention tasks as shown in other studies.

Vera & Montilla (2003) examined six-year-old boys and girls over the course of two months learning a ball-throwing target task. The children were split into one of two practice schedules: blocked or variable. Variable practice is when a single group of skills is practiced using variations of the skill (Shea & Morgan, 1979). An example of a variable practice schedule would be practicing jump shots from five different places around the key in basketball. The variable group showed significantly better performance than the blocked group for acquisition, retention and transfer. Because the study was conducted over a longer period of time than most studies (usually one or two days), results indicate that the effects of variable practice were relatively persistent.

Ste-Marie, Clark, Findlay & Latimer (2004) found learning effects associated with random practice extended to handwriting skills. They conducted three studies with elementary school students for symbol and handwriting tasks. The first study consisted of three phases, acquisition, interpolated and retention. During acquisition participants completed 72 trials of drawing three symbols in either a blocked or random schedule. The interpolated phase consisted of 30 minutes of normal school work (e.g. reading or math). For the retention test, participants were divided further into random and blocked retention groups for both previous conditions. Those in the random acquisition group performed better in retention than those in the blocked acquisition group irrespective of their retention schedule. For the second experiment, a similar procedure was used with a few changes. The students were required to replicate three letters in cursive writing. A transfer test was also included immediately after the retention test. The transfer test consisted of joining the letters together to form a word. Those in the random acquisition schedule were able to perform the transfer test faster than those in the blocked acquisition group. For retention, the random group performed better on two of the letters. While the blocked group performed better on the remaining letter. This was discussed by the authors to be a possible result of the order of practice for the blocked group. The third experiment counterbalanced the order that the blocked group practiced the letters. The random group performed better than the blocked group on both the retention and transfer tests.

Jarus & Gutman (2001) examined the effects of task complexity and cognitive processes on a bean bag throwing target task with children 7.5 to 9.5 years old. There were six experimental groups: 1) blocked practice, with a complex task, involving variation in order of bags to throw as well as the weight of the beanbags 2) blocked practice with a simple task, only varying the weight of the bean bags 3) random practice with a complex task 4) random practice with a simple task 5) combined practice with a complex task and 6) combined practice with a simple task. Combined practice consisted of the first half of the trials (15) being presented in a blocked schedule, followed by the second half (15) being presented in a random schedule. The results showed that there was no significant difference in the movement times between the blocked, random and combined groups for the simple task during acquisition and retention. Similar results were seen between acquisition and retention phases. The blocked groups for the simple task and the complex task did not show a significant difference; however the simple task was performed significantly faster than the complex task for both the random and combined groups during acquisition and retention. Similar results were seen for transfer. Though the simple task group performed faster than the complex task group for the combined schedule, this result was not statistically significant. These results provide important insight into the differences in optimal challenge points between children and adults. The increase of cognitive effort required for the random and combined complex tasks may have been too much information for the children whereas similar tasks for adults would see positive effects of these challenges.

Sullivan, Kantak & Burtner (2008) conducted a study comparing children and adults during a discrete arm movement task with feedback either on 62% of the trials (faded) or on 100% of the acquisition trials. Participants in both age groups and under both feedback conditions improved both accuracy and consistency across the acquisition trials. Children performed with significantly more error during acquisition than the adults. During retention trials, the adults who received feedback on 62% of the acquisition trials performed with increased consistency compared to those who received feedback on 100% of the trials. However, the children who received feedback on 100% of the acquisition trials performed with greater consistency and accuracy during retention than those that received the faded schedule. A third part of this study was a reacquisition test which consisted of 20 extra trials following the retention test. Feedback was provided during the reacquisition test. These trials were examined to indicate if the learners had returned to baseline or had retained some learning benefits from the previous session. During the reacquisition test the children from both feedback conditions performed comparably. The authors suggested that children and adults used feedback differently and that children may need more practice and more gradually reduced feedback in order to learn optimally compared to adults.

**1.4 Self-regulated Learning in Children**

While there is no known literature on self-regulation of practice repetition scheduling for motor tasks involving children, many in the education literature discuss the benefit of self-regulated learning (Boekaerts, 1997; Winne, 1995; Zimmerman & Martinez-Pons, 1990). These papers have focused on the characteristics of learners who are defined as self-regulators. Winne (1995) describes the key characteristics of self-regulators including seeking and retrieving information, monitoring progress towards goals they have set for themselves, and making several types of adjustments based on progress and performance.

A study by Lodico, Ghatala, Levin, Pressley & Bell (1983) examined word pairing and free recall tasks. They taught the participants two strategies for a word pairing task, sentence generation and sentence repetition. They then examined which of the strategies the participants chose for a novel word pairing task. They also examined whether multiple item repetition strategy or single item repetition strategy would be chosen for a novel free recall task. Sentence generation and multiple item strategy are established as the more effective strategies. Sentence repetition occurs when the participant repeats a sentence after it has been read, whereas for sentence generation they have to actually generate the sentence from memory. Multiple item repetition occurs when more than one item is repeated at a time, where single item repetition requires the participant to repeat the same word over and over. When given the choice of which strategy to use on a novel task, many of the students picked the more effective strategy. This supports the idea that children are able to make decisions that will benefit learning, when given the opportunity. This provides evidence towards self-regulation being beneficial for children.

### 1.5 Self-regulation for Motor Tasks in Children

Recently, Chiviacowsky, Wulf, Medeiros, Kaefer & Tani (2008) examined the benefits of learner-regulated KR in ten-year-old children completing a bean bag toss with their non-dominant arm. Participants wore opaque goggles during acquisition and therefore could not see the target. KR was provided about the direction of where the beanbag landed as well as how close it landed to the target. KR was provided when requested during acquisition for the self-regulated group and replicating the schedule of their self-regulated counterpart for those in the yoked group. On average, those in the self-regulated group requested feedback after 28.3% of the 60 acquisition trials. Somewhat of a faded schedule was requested as participants asked for feedback on 29.8% of the trials during the first half of acquisition and on 26.9% of the trials during the second half. Those in the self-regulated group performed with significantly less error than those in the yoked group on a retention test one day after acquisition. The children in the group which self-regulated KR also requested feedback more often after good trials. These findings are similar to those found in similar studies that utilized adult participants (Chiviacowsky and Wulf 2002). Chiviacowsky et al. (2008a) discuss the practical implications of this study as; in situations where children are learning a motor task and they are receiving feedback, that providing the children with the opportunity to request feedback when needed or providing feedback after correct trials may better facilitate learning than the traditional approach of providing feedback after incorrect trials.

Using the same task as Chiviacowsky et al (2008a), Chiviacowsky, Wulf, Medeiros, Kaefer & Wally (2008) examined the effect of feedback request frequency on learning in ten-year-old children. From a group of 60 children, two groups of 20 were created, based on the frequency of which they requested feedback during 60 acquisition trials. The 20 participants that requested feedback the most frequently (average of 39.3 %) formed the more-KR group and the 20 participants that requested feedback the least (average of 8.4%) formed the less-KR group. Both groups increased their accuracy throughout acquisition. On a retention test the following day, those in the more-KR group performed with significantly more accuracy than those in the less-KR group. The authors suggest that the error detection and correction mechanism is developed and refined by the performer comparing his or her intrinsic feedback with extrinsic information. Because children have relatively limited experience, more frequent feedback would facilitate this process. Chiviacowsky et al (2008b), suggest that a higher frequency of feedback might make up for processing differences between children and adults. The last possible explanation provided by the authors is that more frequent feedback may be beneficial compared to less frequent feedback for this particular task when completed by children because this task may be more difficult for children to perform compared to adults.

The examination of the effects of self-regulated practice contexts on learning in children has only very recently been brought to light. The examination of the effects of self-regulated KR for a single task is a good starting point, but much more investigation is needed to understand if the benefits of self-regulated practice contexts seen in adult populations extend to children.

# CHAPTER 2: INTRODUCTION

## 2.1 Introduction

Traditionally, practice of motor skills has been organized by a coach, practitioner or teacher. For example a coach may have athletes practice three specific skills in a specific order, providing feedback only on incorrect attempts and demonstrating the skill once at the beginning of practice. However, there are several practice contexts that can be regulated by the learner themselves such as, the order in which the learner practices the skills, when and what type of feedback is provided and when to view a demonstration. Self- regulation research in the motor learning domain to date has determined that allowing the learner to have control over a portion of the learning environment, such as, practice repetition schedules (Keetch & Lee, 2007; Titzer et al. , 1993; Wu, 2007; Wu & Magill, 2004) feedback scheduling (Chiviacowsky et al., 2002; Chiviacowsky et al.,2005; Janelle et al., 1995; Janelle et al., 1997) use of assistive devices (Hartman, 2007; Wulf et al, 2001; Wulf & Toole, 1999) or viewing of a skilled model (Wrisberg & Pein, 2002; Wulf et al.,2003) can enhance retention of several types of motor skills such as: discrete, (e.g. underhand throw; Chiviacowsky et al., 2002; Chiviacowsky et al.,2005; Janelle et al., 1995; Janelle et al., 1997; golf putt; Wu & Magill, 2004; basketball free throw Wulf et al.,2003; and badminton serve; Wrisberg & Pein, 2002,) serial, ( e.g. key pressing sequences, Wu, 2007, barrier knock down tasks; Titzer et al., 1993, and mouse directed aiming tasks; Keetch & Lee, 2007,) and continuous (e.g. slalom ski movements; Wulf et al, 2001; Wulf & Toole, 1999, and use of a stabilometer; Hartman, 2007.) If the participant is afforded the opportunity to individualize an aspect of practice accordingly, motor learning is improved significantly compared to if they were not afforded the opportunity (e.g. yoked condition). In a yoked condition participants follow an identical schedule for the variable being examined (e.g. feedback or practice repetition schedule) to that of a counterpart in the self-regulated practice variable group. The only difference between the two groups is that the group which self-regulated the practice variable was given a choice. Any differences seen between the two groups could most likely be attributed to the actual decision making involved in the self-regulated condition and not the particular schedule itself. The participants in a self-regulated practice schedule condition are also able to decide how often they switch between the tasks and therefore can decide the amount of contextual interference (CI) involved in acquisition.

The concept of CI was first examined in verbal learning (Battig 1972 & Hiew, 1977 as cited in Shea & Morgan 1979). CI is defined as the interference caused by performing different variations of a skill in a practice context (Magill, 2004).The level of contextual interference can be manipulated by how a given practice session is scheduled. A blocked practice schedule would have relatively little CI compared to an entirely random practice schedule, whereas other types of practice, such as serial, fit somewhere in between on a scale of CI (Shea & Morgan 1979). A CI effect is seen when performers under a high CI condition, such as random practice, perform better on retention and/or transfer tests than those in a lower CI condition, such as blocked practice.

The benefits of practice contexts that are self-regulated are generally viewed as robust across many conditions and tasks when examining a healthy adult population. The benefits of self-regulation have been evident in the practice variables of augmented feedback, (Janelle et al., 1995; Janelle et al., 1997; Chiviacowsky et al., 2002; Chiviacowsky et al.,2005) observational learning, (Wrisberg & Pein, 2002; Wulf et al.,2003) use of assistive devices, (Hartman, 2007; Wulf et al, 2001; Wulf & Toole, 1999) and repetition scheduling, (Keetch & Lee, 2007; Titzer et al., 1993; Wu, 2007;Wu & Magill, 2004) as compared to those in a corresponding yoked practice condition. The benefit of self-regulation in motor learning tasks for young adults has been well established as evidenced by the studies cited above. More recently, the self-regulation of practice variables have been examined in a pediatric population. For example, Chiviacowsky et al (2008a) found that 10-year-old children, similar to adult populations in previous studies, benefited from the opportunity to regulate their KR schedule, with the group that self-regulated KR outperforming the yoked group during retention tests for an underhand throwing task utilizing the non-dominant arm. Furthermore, Chiviacowsky et al. (2008b) found that children benefited from higher frequencies of feedback. This was evidenced by superior retention shown by the children that chose higher frequencies of feedback as compared to those which chose lower frequencies. However, much more investigation is needed to further understand the benefits of self-regulated practice contexts in children. The benefits of self-regulation of practice contexts appear to be quite generalized to a wide variety of contexts and could also, with further study, be found to be generalized to populations other than young adults.

**2.2 Statement of the research problem**

It has been found that allowing the learner to have control over a portion of the learning environment can enhance retention of several types of motor skills in young adults, and more recently, 10-year-old children. If the participant is afforded the opportunity to individualize an aspect of practice, retention of the specific task is improved significantly compared to those who did not have the opportunity to individualize practice.

While the self-regulation of practice variables has been examined in a limited number of populations, the findings from young adults have recently been generalized to a pediatric population. However, only one (e.g. augmented feedback) of the four practice variables that have been extensively examined in the context of self-regulation in adults (augmented feedback, scheduling of repetitions, observational learning and use of assistive devices) have been generalized to children. In each of these practice variables the learner is making a choice. In the case of the self-regulation of repetition scheduling the choice is commonly between three motor tasks and can involve the selection of one or more strategies, such as any combination of blocked-type and random-type schedules. Blocked practice was defined as a practice sequence, uninterrupted by any other task, where all the trials of one task were completed before performing the next task (Schmidt & Lee, 2005). Random practice was defined as a practice sequence where the tasks being practiced were randomly ordered across the trials, where no more than 2 trials of the same task were practiced together. More than one skill was practiced within a block of practice trials (Schmidt & Lee, 2005).Therefore the nature of the decision being made during repetition scheduling differentiates repetition scheduling from other self-regulated practice contexts.

Many novel motor tasks are introduced to children, in sports, classes at school or through other opportunities and the investigation of the self-regulation of practice variables would benefit the development of the best ways in which to teach motor skills in these contexts. In particular, the investigation of self-regulation of repetition scheduling would provide important information to coaches, teachers, practitioners and others about how to best organize learning sessions for children. Therefore the purpose of this thesis was to examine the learning advantages of self-regulation of practice repetition scheduling for a sequence timing task.

**2.3 Predictions based on the Literature**

Based on the extant literature the following predictions were made; 1) Children and adults would show better retention when given the opportunity to choose their practice schedule (SELF) compared to their yoked counterparts to be evidenced by faster movement time, reaction time, and greater recall success in the retention tests (Lodico et al., 1983; Titzer et al., 1993; Wu & Magill, 2004 & Wu, 2007.)

2) Children would choose to switch sequences less often (e.g. blocked type schedule) than the adults. This prediction is based upon Chiviacowsky et al's (2008b) findings that many children will choose a less effective strategy for learning. For a simple motor task, such as key pressing, blocked practice would most likely be an ineffective strategy for learning (Jarus & Gutman, 2001.)

3) As compared to adults, children would demonstrate lower proportional recall success as well as longer movement times and reaction times (Bowien et al., 2006; Olivier et al., 1997; Pollock & Lee, 1997 & Thomas et al. 2000).

# CHAPTER 3: METHODS

## 3.1 Participants

Twenty- four children eight to 15 years old (M = 11.67 years; SD = 2.04) and twenty-four adults, 18 to 25 years old (M = 22.04 years; SD = 2.24) from the community of St. Catharines participated in this study. The participants in the CHILD groups were given the opportunity to be accompanied by a guardian, who did not provide assistance during testing. Participants were assigned to one of four experimental groups based upon the date of the testing session (SELF were tested prior to YOKE) and age group (CHILD or ADULT).The groups were; CHILD-SELF (n=12), CHILD-YOKE (n=12), ADULT-SELF (n=12) and ADULT-YOKE (n=12). Prior to the first session, letters of information as well as an informed consent form were provided to and signed by the participants and guardian (if appropriate). The children were given a Brock Badgers t-shirt upon completion of the study.

## 3.2 Apparatus and Task

Participants were seated in front of a standard desk, 71cm high supporting a 38cmx 38cm Dell computer monitor, a 42cmx 14cm Dell computer keyboard and a PST serial response box (SRT box) from Psychology Software Tools Inc. The SRT box had five numbered, 1cm x1cm, keys placed in a horizontal line with .5cm between each key. The numbers on the SRT box corresponded with those on the computer screen representing each sequence (see figure.1).

The task required the participants to complete three novel five-digit key-pressing sequences using the SRT box. Each sequence consisted of pressing each of the five keys on the SRT box in a specific, unique order. Sequence one consisted of pressing keys

5,4,3,1,2, in sequential order, sequence two was 1,3,4,2,5 and sequence three was 3,2,5,1,4. The to-be completed sequences were visually presented to the participants on the computer monitor (see figure.2.) A key pressing task was chosen because it has been consistently used in the motor learning literature and the timing in milliseconds as well as recall success measurements could be recorded accurately using E-Prime. Three sequences were chosen in order to provide the opportunity for the contextual interference (CI) effect to be shown if a participant followed a schedule conducive to it. The more switches made during acquisition, the greater the opportunity for the benefits of CI. Alberet and Thon (1998) found that the CI effect was most beneficial at three segments of a geometric shape, but the benefits were diminished when a fourth segment was added

The goal of the participants was to complete each sequence as fast and accurate as possible on each trial. E-Prime (version 1.0 Psychology Software Tools, Inc., Pittsburgh, PA, USA) customized the display instructions, countdowns of remaining trials, feedback on performance trials and the display of practice trials. The order of how the sequences were displayed on the computer monitor for the choice screen was counter balanced across participants. For example, one participant viewed the options displayed vertically on a display screen as 1 then 2 then 3 and another viewed them displayed as 2 then 1 then 3. This was important to prevent the participant from following a 1 then, 2, then 3 approach to sequence selection because that was the way it was displayed.

**3.4 Procedure**

At the beginning of the experiment each participant was administered the Peabody Picture Vocabulary test to measure vocabulary comprehension. Participants in the CHILD groups were required to achieve a minimum age equivalent score of 8 years, which was the youngest age included in this study. Participants in the ADULT groups were required to achieve a minimum age equivalent of 18 years, the youngest included in the ADULT groups. Since all instructions for the experiment were presented visually on the computer screen and orally by the researcher, it was important that the participant could understand spoken English. Participants or their guardians also completed the Barthel Index, which indicated the functional ability of the participants to complete several typical daily tasks.

All participants performed a total of 36 acquisition trials; 12 for each sequence. The SELF groups chose which of the 3 sequences they would like to practice prior to each trial. Twelve trials of each sequence were required to be practiced, but the participant could practice the trials in whichever order they chose. Before choosing which sequence to practice, the participant was presented with a screen showing how many trials were left to be practiced for each sequence and which button to press to select each of the trials, for example, for sequence # 1 press 1. Each participant in the YOKE groups followed a schedule identical to a participant in the self-regulated group, but without the choice. The researcher manually entered the practice schedule of the SELF counterpart for the YOKE participant. In an instance where a participant inadvertently chose a trial for which there were no trials remaining, that trial was not included in the subsequent analyses.

The acquisition phase began by showing participants a series of instructions on the computer monitor generated by E-prime (see appendix A35 for descriptions of the instruction screens). Each instruction screen was presented for as long as the participant requested, in order to ensure understanding. Any questions were answered after the instructions were viewed. Following the instructions, participants performed three practice trials typical of the experimental condition of sequences ***not used*** in the experimental testing. The purpose of the practice trials was to give the participants an opportunity to practice the experimental procedure before the acquisition trials began.

At the beginning of each acquisition trial the sequence to-be- practiced was selected on the SRT box either by the participant, in the case of SELF groups or by the researcher, in the case of the YOKE groups. For each acquisition trial for both the SELF and YOKE groups, following the selection of sequence, a screen displaying the sequence to be practiced was displayed for five seconds, followed by a "Ready?"screen for one second. Following the ready screen, a screen with the sequence identification number (1, 2 or 3) with five empty boxes was displayed. Participants were then required to immediately reproduce the pattern on the SRT box that corresponded to the sequence identification number. The screen displaying the number indicating the pattern as well as the five empty boxes was displayed until five keys were pressed by the participant. After the participants completed a trial, the recall success of the sequence order and the increase or decrease in speed was determined by the researcher (e.g., 0= incorrect. 1= correct and slower, 2= correct and faster). The researcher received this information on a screen displaying the total time for the current trial as well as for the previous trial for that sequence, and by watching the participant press the keys. The researcher selected the appropriate feedback display reading "you typed the sequence incorrectly", or "you typed the sequence correctly and slower than last time" or "you typed the sequence correctly and faster than last time". This screen was displayed for five seconds after each trial. Following the feedback screens, the screen informing the participant of how many practice trials of each sequence as well as which keys to press in order to select the next sequence was displayed. When all 12 trials of a given sequence had been completed, that sequence could no longer be chosen (See fig. 3 for a flow-chart representation of an acquisition trial).

Following the acquisition period, the participants coloured in a colouring book for 15 minutes, in order to provide a period of non-practice before the immediate retention test. The immediate retention test consisted of two no KR trials of each sequence, with the order of sequences counterbalanced across participants. Following this, a delayed retention session was scheduled for one day after the last acquisition trial, also consisting of two trials of each of the sequences with the order of sequences counterbalanced across participants, with no feedback provided.

**3.3 Dependent Measures**

E-Prime was used to record the dependent measures in this study. Movement time (MT), reaction time (RT), total time (TT) and recall success (RS) were recorded for each trial. RT was recorded from the time the ready screen was removed to when the first key was pressed on the SRT box. TT was recorded from the time the ready screen was removed to when the last key was pressed on the SRT box. MT was calculated by subtracting the reaction time from the total time. Based on the literature, differences were expected to be seen for MT and RT and therefore they were retained as the main dependent variables for movement measures.Each key press of the sequence was recorded in order to identify any incorrect key presses during the trial. RS was initially recorded by the researcher during acquisition and was later confirmed with the values recorded in E-prime. The recording of temporal and accuracy measures provided an indication of whether or not the participants improved in skill over the acquisition period, and whether they retained any improvements made relatively permanently due to practice in retention.

By recording the number of switches the participants made, we could examine the type of schedule chosen such as a blocked-type schedule or a random-type schedule. Blocked practice is a practice sequence, uninterrupted by any other task, where all the trials of one task are completed before performing the next task (Schmidt & Lee, 2005). For example, if there were three key-pressing sequences to learn, the learner would practice sequence A 10 times, then practice sequence B 10 times and then practice sequence C 10 times. Random practice is a practice sequence where the tasks being practiced are randomly ordered across the trials, where no more than two trials of the same task are practiced together. More than one skill is practiced within a block of practice trials (Schmidt & Lee, 2005). For example, in each 10 trial practice block, sequences A, B and C would be practiced at least three times each. Each sequence is practiced the same amount of times, but they are interdispersed within the practice blocks. The numbers of switches chosen by the groups that self- regulated their schedules were recorded. A switch occurred when a participant chose two different sequences on two consecutive trials. From this we could infer that if learning had taken place, which practice condition was most conductive to learning (i.e. blocked-type or random-type.) As a result, we were then able to examine if the types of schedules chosen differed between the children and adults. For this study we defined random-type practice as the practice of more than one sequence in a subset of three trials. We defined blocked-type practice as the practice of the same sequence for all three trials in a subset of acquisition trials.

**3.5 Data analysis**

Acquisition data for MT (ms), RT (ms), TT (ms) and proportion of RS were analysed using a 2 (practice condition: SELF, YOKE) X 2 (age: ADULT, CHILD) X 2 (blocks of 18 trials, 6 of each pattern) mixed analysis of variance (ANOVA), with block as a within subjects repeated measure. Retention data for MT, RT, TT and RS were analysed using a 2 (practice condition: SELF, YOKE) x 2 (age: ADULT, CHILD) mixed ANOVA.

To determine if participants in the SELF practice conditions employed different switching strategies during the first and second half of acquisition as a function of age, a 2 (age: ADULT, CHILD) x 2 (blocks of 18 trials) ANOVA, with block as a repeated measure was conducted to examine any differences in the total number of switches. The purpose of this analysis was to examine possible switching pattern differences as a function of age.

To determine if participants in the SELF practice conditions chose to switch more often following a relatively “good” trial or a relatively “poor” trial, the RT, MT and RS during acquisition were examined for both trials immediately prior to a switch and those which did not precede a switch. A 2(age: ADULT, CHILD) x 2 (practice condition: SELF, YOKE) x 2 (switch status: prior to a switch, not prior to a switch) mixed ANOVA with repeated measures was conducted for each of RT, MT, and RS. This also provided the opportunity to examine any differences between practice conditions for performance on trials prior and not prior to a switch (Keetch & Lee, 2007 & Wu & Magill, 2004).

Further examination of switching strategies employed by the SELF groups in the context of practice type was conducted by dividing the 36 practice trials into 12 subsections of 3 trials. Including 3 trials in each subset allowed the opportunity to categorize specific portions of practice as either random or blocked type practice. Blocked-type practice was defined as when all three trials practiced in a subset were of the same sequence. Random-type practice was defined as when more than one sequence was practiced in a subset of 3 trials. The proportion of subsets in each block of acquisition representing a random-type schedule, and those representing a blocked-type schedule were calculated. For example a blocked-type practice subset would have the participant practicing sequence 1 three times in a row, whereas a random-type practice subset would have the participant practicing sequence 1 followed by sequence 2 and then sequence three. A 2 (age: ADULT, CHILD) x 2 (practice schedule type: BLOCKED-TYPE, RANDOM-TYPE) x 2 (blocks of 6 subsets [3 trials in each subset]) ANOVA with block as a repeated measure was conducted. All alpha levels were at $p < .05$.

Acquisition data for MT (ms), RT (ms) and proportion of RS were analysed using a 2 (age: ADULT, CHILD) X 2 (blocks of 18 trials, 6 of each pattern) mixed analysis of variance (ANOVA), with block as a within subjects repeated measure. Retention data for MT, RT and RS were analysed using a 2 (age: ADULT, CHILD) mixed ANOVA.

Any statistically significant interactions found during analysis were subjected to a Tukey's honest significant difference post hoc analysis.

## CHAPTER 4: RESULTS

### *4.1 Recall Success*

#### *4.1a Acquisition*

No significant differences were found between age and practice conditions (see left side of figure 4.) Participants in the CHILD-SELF practice condition had a mean proportional RS of .77 (*SD* = .17), while the participants in the CHILD-YOKE practice condition had a mean proportion RS of .85 (*SD* = .08) for block one. For block two, the CHILD-SELF practice condition demonstrated a mean RS of .85 (*SD* = .082) and the CHILD-YOKE, .87 (*SD* = .08). The ADULT –SELF practice condition demonstrated a mean proportional RS of .84 (*SD* = .12), while the ADULT-YOKE practice condition demonstrated a mean proportional RS of .84 (*SD* = .07) for block one and a RS of .85 (*SD* = .08) and .88 (*SD* = .09), for block two. Main effects for block $F(1, 44) = 2.692$, $p = .108$; age $F(1, 44) = .566$, $p = .456$; and practice condition $F(1, 44) = 2.264$, $p = .140$ were not statistically significant. Interactions between block and age $F(1, 44) = .168$, $p = .667$; block and practice condition $F(1, 44) = .113$, $p = .738$; and finally between block, age and practice condition, $F(1, 44) = 1.180$, $p = .283$ were also not statistically significant. Overall all groups maintained a relatively high level of RS throughout acquisition, with no significant differences in RS revealed between the groups.

For the age analysis the main effects for age $F(1, 46) = .56$, $p = .46$ and block $F(1, 46) = 2.73$, $p = .11$ as well as the interaction between block and age $F(1, 46)$ $F = .19$, $p = .67$ were not significant (see figure 10).

#### *4.1b Retention*

The relatively high level of recall success demonstrated by the experimental groups during blocks one and two of the acquisition period was not maintained during the retention test (see right side of figure 4). The main effect for practice condition was statistically significant, $F(1, 48) = 4.558, p = .038$. The participants in the SELF condition demonstrated greater mean recall success (M=0.39; $SD = .26$), compared to those in the YOKE practice condition (M= 0.25; $SD = .20$). The main effect for age $F(1, 48) = 1.344, p = .25$, as well as the interaction between age and practice condition $F(1, 48) = 2.579, p = .12$ were not statistically significant (see right side of figure 4).

For the age analysis the main effect for age $F(1, 46) = 1.21, p = .28$ was not significant (see figure 10).

***4.2 Total Time***

*4.2a Acquisition*

The interaction between block and age was significant $F(1, 44) = 8.52, p = .006$. For block one, the participants in the ADULT groups (M = 1690.45ms; $SD$ = 289.05ms) performed with faster total times than those in the CHILD groups (M = 2472.33ms; $SD$ = 726.96ms) irrespective of practice condition. For block two, the participants in the ADULT groups (M = 1448.02ms; $SD$ = 259.11ms) once again performed with faster total times than those in the CHILD groups (M = 1962.24 ms; $SD$ = 442.89ms) irrespective of practice condition. The ADULT-SELF group had a mean average TT of M = 1777.58 ms ($SD$ = 334.55 ms) during block one and M= 1544.33 ms ($SD$ = 303.56 ms) during block two. The ADULT-YOKE group had a mean average TT of M = 1603.32 ms ($SD$ = 214.96 ms) during block one and M= 1351.71ms ($SD$ = 167.31 ms) during block two. The CHILD-SELF group had a mean average TT of M = 2515.54ms ($SD$ = 894.96 ms) during block one and M= 1965.85 ms (*SD* = 514.94 ms) during block two. The CHILD-YOKE group had a mean average TT of M = 2429.12 ms (*SD* = 547.70 ms) during block one and M= 1958.64 ms (*SD* = 380.72 ms) during block two. Those in both the ADULT and CHILD groups decreased their total times from block one to block two during acquisition, with means of 1690.45ms (*SD* = 289.05ms) and 2472.33ms (*SD* = 726.96 ms) for block one respectively, and 1448.02ms (*SD* = 259.11ms) and 1962.24ms (*SD* = 442.89ms) for block two respectively (see figure 6).

There was a main effect for block $F(1, 44) = 67.31$ $p = .001$ with a mean of 2081.39ms (*SD* = 674.97ms) for block one and 1705.13ms (*SD* = 443.12ms) for block two as well as for age $F(1, 44) = 25.40$ $p = .001$. The mean TT for ADULT, M = 1448.01ms (*SD* = 259.11ms,) was significantly faster than the mean for CHILD M =1962.24ms (*SD* = 442.89ms.) The following effects and interactions were not significant: practice condition $F(1, 44) = .80$, $p = .38$, interaction between practice condition and age $F(1, 44) = .28$, $p = .60$, interaction between block and practice condition $F(1, 44) = .11$, $p = .74$ and the interaction between practice condition, age and block $F(1, 44) = .283$, $p = .60$.

*4.2b Retention*

The main effect for practice condition failed to reach statistical significance $F(1, 40) = 1.72$ $p = .42$ with a mean of 1911.08ms (*SD* = 573.30 ms) for the YOKE condition and 2550.99 ms (*SD* = 1.32E3 ms) for the SELF practice condition. The main effect for age $F(1, 40) = .13$, $p = .78$, and the interaction between age and practice condition, $F(1, 40) = 2.40$ $p = .13$ were not statistically significant at $p > .05$ (see right side of figure 5).

***4.3 Movement Time***

*4.3a Acquisition*

The interaction between block and age was significant $F\,(1, 44) = 10.915, p =$ .002. For block one, the participants in the ADULT groups (M = 1194.40ms; $SD$ = 226.64ms) performed with faster movement times than those in the CHILD groups (M = 1811.01 ms; $SD$ = 552.47ms) irrespective of practice condition. For block two, the participants in the ADULT groups (M = 1038.99ms; $SD$ = 184.77ms) once again performed with faster movement times than those in the CHILD groups (M = 1447.10 ms; $SD$ = 372.57ms) irrespective of practice condition. The ADULT-SELF group had a mean average MT of M = 1235.86 ms ($SD$ = 259.56 ms) during block one and M= 1089.73 ms ($SD$ = 212.34 ms) during block two. The ADULT-YOKE group had a mean average MT of M = 1152.93 ms ($SD$ = 190.48 ms) during block one and M= 988.24 ms ($SD$ = 143.78 ms) during block two. The CHILD-SELF group had a mean average MT of M = 1850.91ms ($SD$ = 669.46 ms) during block one and M= 1469.66 ms ($SD$ = 437.50 ms) during block two. The CHILD-YOKE group had a mean average MT of M = 1771.12 ms ($SD$ = 431.90 ms) during block one and M= 1424.53 ms ($SD$ = 312.61ms) during block two. Those in both the ADULT and CHILD groups decreased their movement times from block one to block two during acquisition, with means of 1194.40ms ($SD$ = 226.64ms) and 1811.02ms ($SD$ = 552.47ms) for block one respectively, and 1038.99ms ($SD$ = 184.77ms) and 1447.10ms ($SD$ = 372.57ms) for block two respectively (see figure 6).

There was a main effect for block $F\,(1, 44) = 67.7\ p = .001$ with a mean of 1502.7ms ($SD$ = 521.13ms) for block one and 1243.04ms ($SD$ = 356.59ms) for block two as well as for age $F\,(1, 44) = 25.2, p = .001$. The mean MT for ADULT, M = 1038.99ms

(*SD* = 184.77ms,) was significantly faster than the mean for CHILD M =1447.10ms ( *SD* = 372.57ms.) The following effects and interactions were not significant: practice condition $F$ (1, 44) = .575, $p$ = .452 interaction between practice condition and age $F$ (1, 44) = .021, $p$ = .885 interaction between block and practice condition $F$ (1, 44) = .16, $p$ = .899 and the interaction between practice condition, age and block $F$ (1, 44) = .178, $p$ = .675.

For the age analysis the main effects for age $F$ (1, 46) = 26.06, $p$ = .001 and block $F$ (1, 46) = 70.48, $p$ = .001 as well as the interaction between block and age $F$ (1, 46) F = 11.36, $p$ = .002 were significant (see figure 11).

*4.3b Retention*

The main effect for practice condition just failed to reach statistical significance $F$ (1, 40) =3.073 $p$ = .09 with a mean of 1348.58 ms (*SD* = 353.18 ms) for the YOKE condition and 1673.39 ms (*SD* = 805.89 ms) for the SELF practice condition. The main effect for age $F$ (1, 40) = 2.807, $p$ = .103, and the interaction between age and practice condition, $F$ (1, 40) = .10 $p$ = .921 were not statistically significant at $p > .05$ (see right side of figure 6).

For the age analysis the main effect for age $F$ (1, 46) = 2.46, $p$ = .13 was not significant (see figure 11).

***4.4 Reaction Time***

*4.4a Acquisition*

The participants in the ADULT groups (M = 409.03ms; *SD* = 108.24ms) performed with faster RT than those in the CHILD groups (M=515.15ms; *SD* = 163.61ms) irrespective of practice condition, as supported by a main effect for age $F$ (1,

44) = 10.057 $p$ = .003. The main effect for block $F$ (1, 44) = 29.877 $p$ = .001 was also significant. RT decreased across blocks during acquisition with a mean of 578.69ms ($SD$ = 204.48ms) for block one and a mean of 462.09ms ($SD$ = 147.34ms) for block two. However, the following effects and interactions were not significant; practice condition $F$ (1, 44) = .78 $p$ = .382., interaction between age and block $F$ (1, 44) = 1.922 $p$ = .173, interaction between block and practice condition $F$ (1, 44) = 2.75, $p$ = .603, interaction between practice condition and age $F$ (1,44) = 1.56 $p$ = .218, and interaction between practice condition, age and block $F$ (1, 44) = .270 $p$ = .606 (see left side of figure 7).

For the age analysis the main effects for age $F$ (1, 46) = 9.98, $p$ = .003 and block $F$ (1, 46) = 30.85, $p$ = .001 were significant. The interaction between block and age $F$ (1, 46) F = .20, $p$ = .17 was not significant (see figure 12).

*4.4b Retention*

The main effects for age $F$ (1, 40) = 1.323, $p$ = .258, and practice condition $F$ (1, 40) = .001, $p$ = .998 were not statistically significant. The interaction between group and age $F$ (1, 40) = .395, $p$ = .534 was also not significant (see right side of figure 7).

For the age analysis the main effect for age $F$ (1, 46) = 1.38, $p$ = .25 was not significant (see figure 12).

***4.5 Switches and Scheduling***

*4.5a Number of Switches*

On average, participants in the SELF-ADULT group switched on 50.2% of the trials during acquisition, while the SELF-CHILD group switched on 65.7% of the trials. In order to examine any changes in the number of switches between the first and second half of acquisition, the 36 acquisition trials were split into two blocks of 18 trials. The main effects for age $F(1, 24) = 1.509$ $p = .232$, and block $F(1, 24) = .753$, $p = .395$ as well as the interaction between age and block $F(1, 24) = .398$, $p = .534$, were not statistically significant (see figure 8).

*4.5b Recall Success*

The proportional RS of the trials which preceded a switch and those which did not precede a switch was examined. The main effects for age, $F(1, 44) = .789$, $p = .379$, practice condition, $F(1, 44) = 1.963$, $p = .168$ and switch status $F(1, 44) = .007$ $p = .932$ were not statistically significant. The interactions between switch status and practice condition, $F(1, 44) = .004$, $p = .950$, switch status and age, $F(1, 44) = .037$, $p = .849$, age and practice condition, F $(1, 44) = 1.741$, $p = .194$ and age, practice condition and switch status, $F(1, 44) = .014$, $p = .906$ were not statistically significant (see appendix 23 A for means). These results indicate that participants in the SELF groups were not switching more often on trials that were recalled successfully than those that were not recalled successfully.

*4.5c Movement Time*

The MTs of the trials which preceded a switch and those which did not precede a switch were examined. This analysis was conducted to examine whether participants chose to switch after trials that were faster or slower than the trials after which they did not choose to switch. The main effect for age, $F(1, 44) = 20.75$, $p = .001$ was significant with the ADULT groups (M = 1116.18 ms; *SD* = 209.7ms) performing with a faster MT, regardless of switch status and practice condition than the CHILD groups (M = 1648.54ms; *SD* = 504.8ms) for trials prior to a switch as well as trials that did not precede a switch (ADULT M = 1094.2ms; *SD* = 182.91ms) and (CHILD M = 1660.90ms; *SD* =

631.37ms). The main effects for practice condition, $F(1, 44) = .397$ $p = .532$ and switch status, $F(1, 44) = .019$, $p = .890$ were not statistically significant. The interactions between switch status and practice condition, $F(1, 44) = .757$ $p = .389$, switch status and age, $F(1, 44) = .248$, $p = .621$, age and practice condition, $F(1, 44) = .029$, $p = .865$, and age, practice condition and switch status, $F(1, 44) = .534$, $p = .469$ were not statistically significant.

*4.5d Reaction Time*

The RTs of the trials which preceded a switch and those which did not precede a switch were examined. This analysis was conducted to examine whether participants chose to switch after trials that had faster or slower RTs than the trials after which they did not choose to switch. The main effect for age, $F(1, 44) = 7.272$, $p = 0.01$ was significant with the ADULT groups (PRE_SWITCH M = 443.15ms; *SD* =123.98ms, NON_PRE_SWITCH M = 457.78ms; *SD* =130.50ms) performing with a faster reaction time, regardless of switch status and practice condition than the CHILD groups (PRE_SWITCH M = 605.52ms; *SD* =216.95ms, NON_PRE_SWITCH M = 578.92ms; *SD* = 267.15ms). The main effects for practice condition, $F(1, 44) = .645$ $p = .426$, and switch status, $F(1, 44) = .096$ $p = .758$ were not statistically significant. The interactions between switch status and practice condition, $F(1, 44) = .101$ $p = .753$, switch status and age, $F$, $(1, 44) = 1.138$, $p = .292$, age and practice condition, $F(1, 44) = 1.714$, $p = .197$, and age, practice condition and switch status, RT, $F(1, 44) = .007$, $p = .936$ were not statistically significant.

*4.5e Proportions of Random and Blocked-type Practice*

By recording the number of switches the participants made, we could examine the type of schedule chosen such as a blocked-type schedule or random-type schedule. To examine if, similar to the participants in the study conducted by Wu (2007), participants changed from a more blocked-type practice schedule to a more random-type practice schedule, further examination of switching strategies employed by the SELF groups was conducted by dividing the 36 practice trials into 12 subsections of three trials. Including three trials in each subset allowed the opportunity to categorize specific portions of practice as either random or blocked-type practice. The proportion of subsets in each block of acquisition representing a random-type schedule, and those representing a blocked-type schedule were calculated. A block x age x practice schedule type interaction $F(1, 44) = 4.535, p = .039$ was found to be significant for those in the SELF groups. The results of the post hoc analysis revealed that the ADULT group spent almost twice the amount of trials (M = 0.38; *SD* = 0.33) that the CHILD group (M = 0.21; *SD* = 0.40) did in a blocked-type practice schedule during block one and therefore the CHILD group (M = 0.79; *SD* = 0.40) spent more of the trials in a random-type practice schedule than adults (M = 0.63; *SD* = 0.33). During block two, the CHILD (BLOCKED M = 0.25; *SD* = .39) and ADULT (BLOCKED M = 0.26; *SD* = 0.37) group spent an equal amount of trials in each practice type (see figure 9).

## CHAPTER 5: DISCUSSION AND CONCLUSIONS

### *5.1 Introduction to the discussion*

The purpose of this thesis was to examine the effects of the self-regulation of practice repetition scheduling on learning a motor task as compared to a yoked practice schedule in children and adults. Though Chiviacowsky et al. (2008a) and Chiviacowsky et al. (2008b) extended the benefits of self-regulation to children individualizing their KR schedule, it was not known if the same benefits would be extended to children determining their repetition schedule. In the case of the self-regulation of repetition scheduling the choice is commonly between three motor tasks and can involve the selection of one or more strategies, such as any combination of blocked-type and random-type schedules. Therefore the nature of the decision being made during repetition scheduling differentiates repetition scheduling from other self-regulated practice contexts.

### *5.2 The effects of self-regulation*

The first hypothesis for this thesis stated that children and adults would show better retention when given the opportunity to choose their practice schedule compared to their yoked counterparts, to be evidenced by faster MTs, RTs and greater RS during the retention period (Lodico et al. 1983; Titzer et al 1993; Wu & Magill, 2004; Wu, 2007). This hypothesis was partially supported because those in the SELF conditions produced significantly greater proportional RS compared to those in the YOKE conditions during retention, regardless of age.

The literature to date has been convincing that allowing an adult participant to have control over their own practice repetition schedule is beneficial to learning of a motor task (Keetch & Lee, 2007; Titzer et al., 1993; Wu & Magill, 2004 & Wu, 2007). Titzer et al.(1993) found that when examining the self-regulation of a computer simulated barrier knock-down task, adult participants in the self-regulated group performed with less error than those in the blocked group, (there was not a yoked group). Similarly, Wu & Magill (2004) found that adult participants in a self-regulated condition produced lower error scores, based on distance from a target than those in a yoked condition on retention tests for a golf putting task. Wu (2007) once again found that adults in a self-regulated group performed with less relative timing error on retention tests than those in a yoked group for a key pressing task.

The results of the current study strengthen this argument, in that both age groups under the SELF practice condition recalled a greater proportion of the sequences correctly during retention than those under the YOKE practice condition. Interestingly, the participants under the SELF practice condition recalled the sequence correctly, on only 39% of the retention trials. While this is significantly more often than the average of 25% of the trials achieved by those under the YOKE practice condition, it is much lower than one would expect. Keetch & Lee (2007) found that participants in the self-regulated groups actually performed with less error during retention than during acquisition, with neither acquisition nor retention reaching above an average of 2.5 of the possible five cursor errors. The differences of such a striking decline in RS between acquisition and retention for the current study and the decrease in cursor error in the study conducted by Keetch & Lee (2007) may be explained by how information was presented to the learner during acquisition.

The first explanation to consider is that the type of KR presented to the participant after each trial was different between the two studies. The current study used a qualitative form of feedback, indicating to the participant if they entered the sequence correctly and if he or she completed the sequence faster or slower than last time. The study by Keetch & Lee (2007) provided the participant with three pieces of KR information, total movement time for that trial, pattern accuracy and cursor accuracy. The movement time information provided by Keetch & Lee (2007) would be considered quantitative. Kilduski & Rice (2003) found that participants who received quantitative feedback or a combination of quantitative and qualitative feedback during acquisition of a motor task performed with less error on retention tests than those who received only qualitative KR. Therefore, Keetch & Lee (2007) provided feedback that was more beneficial for retention than the feedback provided in the current study, which could account for the differences between the two studies in the amount of error during retention.

A second explanation is that in the current study, the entire sequence was presented for five seconds *prior* to the participant being required to replicate the sequence, whereas in the study by Keetch & Lee (2007,) participants were not presented the given pattern prior to each trial. In the study by Keetch & Lee (2007) the patterns were presented concurrently to the participant replicating the correct pattern and order of clicks. This is an important difference in the terms of CI. CI is an empirical effect that occurs when more than one task is learned together (Lee, Wishart, Cunningham & Carnahan, 1997). CI is high when tasks are interdispersed amongst each other, such as in random practice and CI is low when all the trials of one task are practiced together before moving on to the next task, such as in blocked practice. Low CI generally facilitates greater performance during acquisition than higher CI for simple tasks. Interestingly, the opposite is true for retention (Shea & Morgan 1979). During acquisition, most participants in the current study chose a random-type practice schedule; thus, it would be expected that all the groups would perform with greater RS in retention than during acquisition. If the participants had chosen mostly blocked-type schedules, it would be expected they would perform with degraded RS in retention. Therefore an explanation is needed as to why the participants in this study show performance patterns typical of what would be expected for blocked practice.

The answer may be that the CI effect was largely reduced by the presentation of the to-be- learned pattern prior to each trial. One explanation of why the CI effect is beneficial is explained by the forgetting and reconstruction hypothesis (Lee & Magill, 1983; 1985). A key part of this hypothesis, examined by Lee et al (1997) is the action planning that occurs prior to a trial during acquisition. This hypothesis predicts that blocked practice produces better performance during acquisition because a previously constructed action plan is always in working memory. This is because the same task is repeated over and over during blocked practice. During random practice, the action plan cannot remain the same for each trial as the tasks switch, and therefore there is interference of the other tasks from one practice trial to another for a given task. Because of this interference, the action plan needs to be reconstructed each time the given task is presented. Lee et al. (1997) found that by introducing action plan information prior to a practice trial during random practice, the benefits of the random practice were greatly reduced. In fact, the introduction of the information prior to a trial produced a pattern of absolute constant error similar to blocked practice during acquisition and even more error than blocked practice during retention. The presentation of the sequence to be practiced, prior to each acquisition trial in the current study, most likely had a similar effect. This unexpected result provides strength to the argument that the benefits of self-regulation go beyond possible CI effects. Even though the participants all practiced the task under lower contextual interference, those that were given the opportunity to choose their practice schedule recalled the task correctly a greater percentage of the time than those who were not. This suggests that the benefits of self-regulation of practice scheduling persist when the CI effect is diminished for both children and adults.

The benefits of self-regulation of practice schedules were not extended to the timing measures of this study in retention. The measures of RT and MT showed no significant differences between practice conditions. During acquisition, the pattern information was provided prior to each trial and was not needed to be reconstructed. Therefore the participant could expend more resources to reducing MT and RT. Both the adults and children significantly decreased their MT and RT across blocks during acquisition. During retention the action plan needed to be reconstructed for each trial and therefore required more resources, leaving less for movement measures. This is a characteristic commonly seen in motor skill performance (Magill 2004).

The second hypothesis of this thesis stated that children would choose to switch sequences less often (e.g. blocked type schedule) than the adults. This prediction was not supported as no significant differences were found between the average number of switches made between children and adults in the self-regulated groups, in fact there was a trend shown that indicated that children (65.7% of the trials ) switched more often than adults (50.2% of the trials) during acquisition. To further investigate the types of strategies chosen by the self-regulated groups, the switching patterns were examined. In an analysis similar to those conducted by Keetch & Lee (2007) and Wu (2007) the proportional RS, MT and RT were compared for each self-regulated group for both the trials prior to the participant deciding to switch patterns, and the trials after which no switch occurred. This would reveal if participants were switching more often after trials with accurate and faster responses ("good trials") or after trials which were incorrect or had slower movement and reaction times ("poor trials"). Keetch & Lee (2007) found that adult participants performed with faster movement times and with less error on a cursor pattern task on trials prior to a switch compared to those that did not precede a switch. The current study revealed that there were no significant differences in the RS, MT or RT between the trials prior to a switch and the trials which were not followed by a switch for either age group. This is not consistent with the findings of Keetch & Lee (2007) and Wu (2007) who found that participants chose to switch tasks following a "good" trial. The results of the present study suggest that both the children and adults chose very similar strategies and did ***not*** base their decision to change on their performance.

Though no particular strategy was evident, further analysis was conducted to examine if the participants' strategies may have differed during the first and second halves of acquisition. Wu (2007) found that adult participants chose a more blocked schedule in the first half of practice and chose a more random or serial type schedule in the second half of practice. In this study, the percent of trials prior to a switch during the first half of acquisition (60.2 %) and the percent of trials prior to a switch during the second half of acquisition (55.1%) did not differ significantly for either age group. Further examination of switching strategies employed by the SELF groups was conducted to examine if similar to the participants in the study conducted by Wu (2007) participants changed from a more blocked-type practice schedule to a more random-type practice schedule. Though both the CHILD and the ADULT groups chose a random-type practice schedule more often than a blocked-type practice schedule throughout acquisition (during blocks one and two,) the ADULT group spent almost twice the amount of trials ( M = 0.38; *SD* = 0.33) that the CHILD group (M = 0.21; *SD* = 0.40) did in a blocked-type practice schedule during block one. During block two, the CHILD (BLOCKED M = 0.25; *SD* = .39) and ADULT (BLOCKED M = 0.26; *SD* = 0.37) group spent an equal amount of trials in blocked practice. This suggests the adults chose a similar strategy to those in the study by Wu (2007). This strategy may have been more effective in the study by Wu (2007) because of how the information was presented to the participant during acquisition, including the type of KR (quantitative) and the timing of action plan information. A pre-test was conducted for this study and the pattern itself was the same for all sequences, with only the timing goals changing. The total numbers of trials were also quite different (e.g. 90 in Keetch & Lee (2007) vs. 36 in the current study). The amount of practice can affect learning, with more practice resulting in greater learning. Several studies examining varying types of key pressing and timing sequences have utilized more acquisition trials. Chiviacowsky & Wulf (2002; 2005) utilized 60 acquisition trials and Wilde et al. (2005) used 720 acquisition trials. The current study used 36 acquisition trials in order to be sensitive to the attention capabilities of children. Several studies in motor behavior have used 30 acquisition trials for child participants (Boswell et al. 1974; Jarus & Goverover, 1999 & Jarus & Gutman, 2001). Though the children appear to have maintained the same mostly random-type strategy throughout acquisition, the CI benefits of the random-type practice schedule seem to be diminished by the presentation of action plan information prior to each acquisition trial.

### *5.3 Comparison of Children and Adults*

The third hypothesis stated that compared to adults, children would demonstrate lower proportional RS as well as longer MTs and RTs. This hypothesis was partially supported. Both adults and children significantly decreased both their RT and MT from the first half, to the second half of acquisition. As predicted, the adults performed with faster MTs and RTs than the children during acquisition. This is consistent with the findings of Thomas et al. (2000), where adults performed with significantly faster movement times than children during acquisition of a rapid aiming task. This finding is also consistent with the findings of Pollock & Lee (1997) who found that adults' performances received higher points than children during acquisition for a modified crokinole task. Adam, Poarthoens & Pratt (2006) examined both an aiming task and a key pressing task in children and caution against comparing aiming and pointing tasks to key pressing tasks, especially in children as they appear to be mediated by different (early and late) selection mechanisms which develop along different time courses. Interestingly, in the current study there were no significant differences in performance between children and adults' MTs and RTs during retention. This is contrary to the findings of Pollock & Lee (1997) who found that the age differences found in acquisition persisted during retention. There is evidence that although children process information for immediate recall (Boswell, Sanders & Young 1974) and the use of precues (Olivier, Ripoll & Audiffren, 1997) similarly to adults by age eight, movement characteristics such as reaction time and movement time are slower in children (Bowien, Smits-Engelsman, Sugden & Duysens, 2006 & Olivier et al., 1997). Since there was less processing of the pattern information involved in the participants' responses during acquisition due to the provision of task information prior to each trial, the movement characteristics (RT, MT) may have been more predominant in cognitive processing during acquisition than during retention. The modified crokinole task, utilized by Pollock & Lee (1997) would also require minimal information processing, which may account for the discrepancy between Pollock & Lee (1997) and the current findings.

The second part of this hypothesis predicted that children would produce lower RS than adults during acquisition and retention and was not supported as evidenced by absent main effects for age during retention and acquisition. RS required greater use of information processing during retention when pattern information was not provided prior to each trial than during acquisition when it was provided. The movement characteristics (MT and RT) also required information processing during both acquisition and retention. The cognitive resources were spread more thinly during retention, as RS required more cognitive resources than during acquisition. This may help explain the increases in MT and especially RT from the end of acquisition to retention. By age eight, the use of precues and immediate recall, both used in the RS measure of this task are similar to those of adults (Boswell, et al., 1974 & Olivier, et al., 1997).

***5.4 Limitations***

Though the results of this study have shown that self-regulation of a practice repetition schedule produces better RS in retention than those in a yoked group, under less than ideal learning conditions, no age differences were found during retention. A more ideal (e.g. more practice trials, the inclusion of quantitative feedback) practice environment in future studies may be more sensitive to any age-related differences. The provision of the action plan information prior to each trial during acquisition may have lessened the beneficial effects of self-regulation in this study.

### *5.5 Application of the findings*

The current study provides valuable information to coaches, teachers and practitioners about the ideal learning environment for children, though further study is needed to extend these findings to more naturalistic tasks such as in sports. What can be taken away by the practitioners, from these results, is that providing a child with the opportunity to self-regulate the order of practice, produces greater recall during retention than if they are not given the opportunity to choose.

### *5.6 Summary*

In summary, participants given the opportunity to self-regulate their practice repetition schedule have been shown to have greater RS during retention than those under a yoked practice condition, regardless of age. The benefit of self-regulation over a yoked schedule persisted even when it appears that the CI effect was diminished for all participants.

## Figure Captions

Figure 1. Photograph of the experimental set up showing the computer screen displaying the sequence and the SRT box.

Figure 2. An example of sequence #1 displayed on the computer screen.

Figure 3. A flow chart representation of the instruction sequencing during acquisition. The duration that each screen is presented for is presented in brackets.

Figure 4. Recall Success (RS) for the self-controlled and yoked experimental conditions as a function of age across the acquisition (block 1 and block 2) and retention period.

Figure 5. Total Time (TT) for the self-controlled and yoked experimental conditions as a function of age across the acquisition (block 1 and block 2) and retention period.

Figure 6. Movement Time (MT) for the self-controlled and yoked experimental conditions as a function of age across the acquisition (block 1 and block 2) and retention period.

Figure 7. Reaction Time for the self-controlled and yoked experimental conditions as a function of age across the acquisition (block 1 and block 2) and retention period.

Figure 8. Average percent of trials prior to a switch for the SELF-CHILD and SELF-ADULT groups for blocks 1 and 2 during acquisition.

Figure 9. Proportion of blocks 1 and 2 under blocked and random-type practice conditions for ADULT and CHILD SELF groups.

Figure 10. Recall Success (RS) for CHILD and ADULT during acquisition and retention

Figure 11. Movement Time (MT) for CHILD and ADULT during acquisition and retention

Figure 12. Reaction Time (RT) for CHILD and ADULT during acquisition and retention

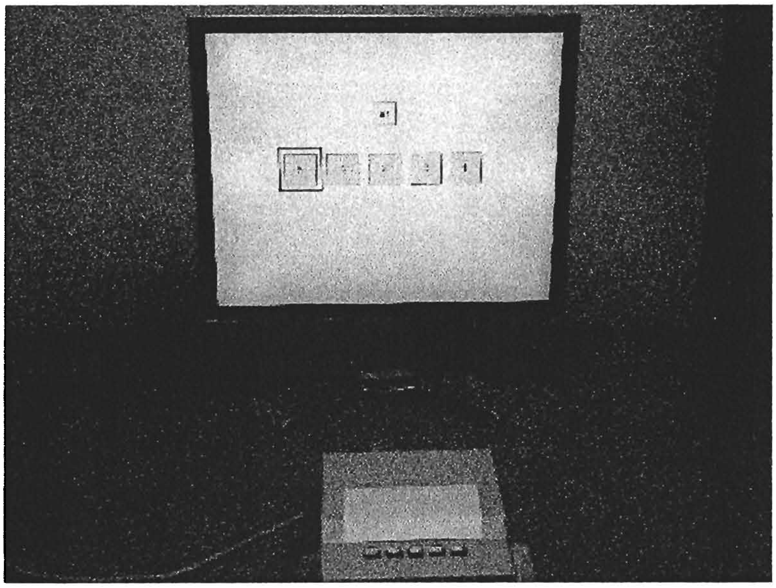


Figure 1.

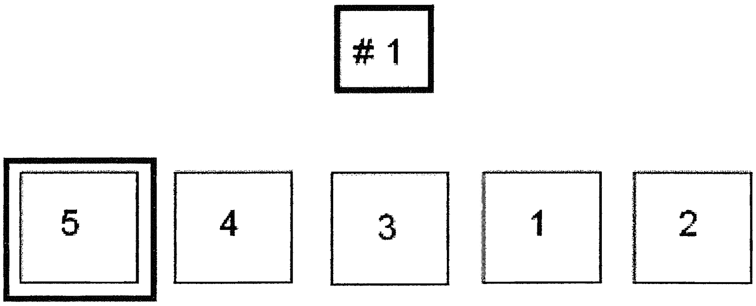



Figure 2.

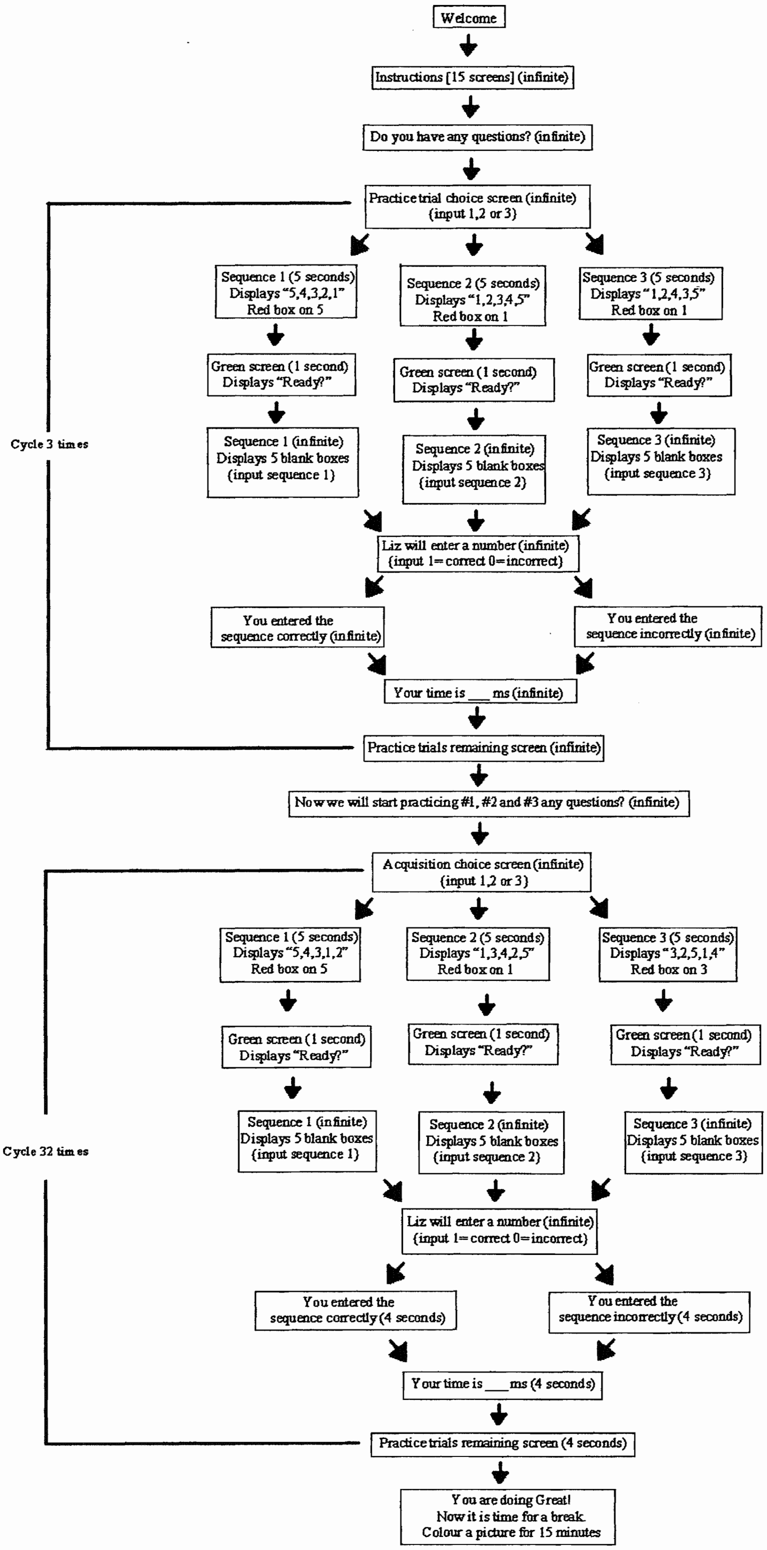

Welcome
Instructions [15 screens] (infinite)
Do you have any questions? (infinite)
Practice trial choice screen (infinite) (input 1,2 or 3)
Sequence 1 (5 seconds) Displays "5,4,3,2,1" Red box on 5
Sequence 2 (5 seconds) Displays "1,2,3,4,5" Red box on 1
Sequence 3 (5 seconds) Displays "1,2,4,3,5" Red box on 1
Green screen (1 second) Displays "Ready?"
Green screen (1 second) Displays "Ready?"
Green screen (1 second) Displays "Ready?"
Cycle 3 times
Sequence 1 (infinite) Displays 5 blank boxes (input sequence 1)
Sequence 2 (infinite) Displays 5 blank boxes (input sequence 2)
Sequence 3 (infinite) Displays 5 blank boxes (input sequence 3)
Liz will enter a number (infinite) (input 1=correct 0=incorrect)
You entered the sequence correctly (infinite)
You entered the sequence incorrectly (infinite)
Your time is ___ ms (infinite)
Practice trials remaining screen (infinite)
Now we will start practicing #1, #2 and #3 any questions? (infinite)
Acquisition choice screen (infinite) (input 1,2 or 3)
Sequence 1 (5 seconds) Displays "5,4,3,1,2" Red box on 5
Sequence 2 (5 seconds) Displays "1,3,4,2,5" Red box on 1
Sequence 3 (5 seconds) Displays "3,2,5,1,4" Red box on 3
Green screen (1 second) Displays "Ready?"
Green screen (1 second) Displays "Ready?"
Green screen (1 second) Displays "Ready?"
Cycle 32 times
Sequence 1 (infinite) Displays 5 blank boxes (input sequence 1)
Sequence 2 (infinite) Displays 5 blank boxes (input sequence 2)
Sequence 3 (infinite) Displays 5 blank boxes (input sequence 3)
Liz will enter a number (infinite) (input 1=correct 0=incorrect)
You entered the sequence correctly (4 seconds)
You entered the sequence incorrectly (4 seconds)
Your time is ___ ms (4 seconds)
Practice trials remaining screen (4 seconds)
You are doing Great! Now it is time for a break. Colour a picture for 15 minutes

Figure 3.

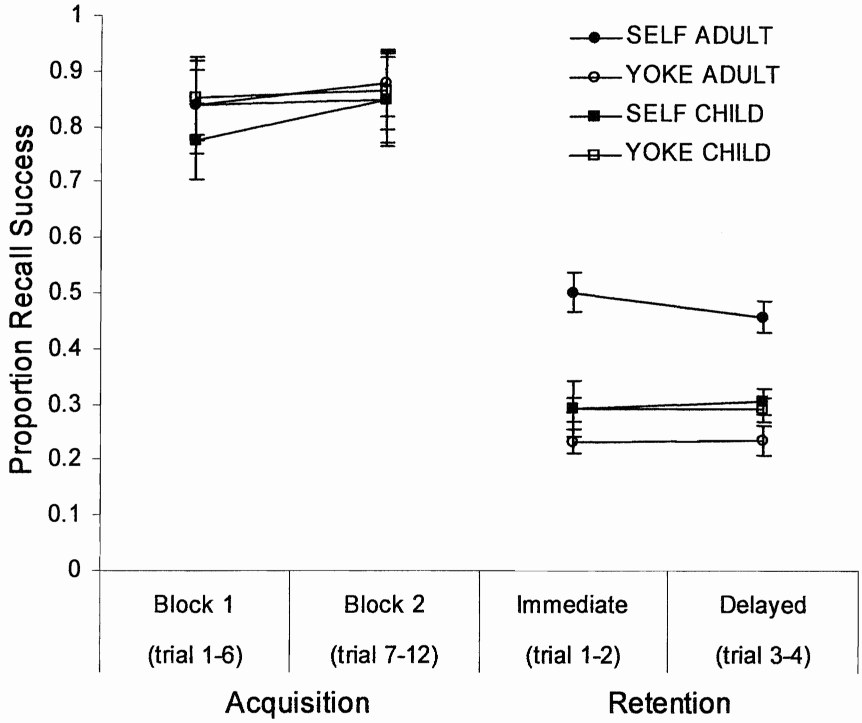
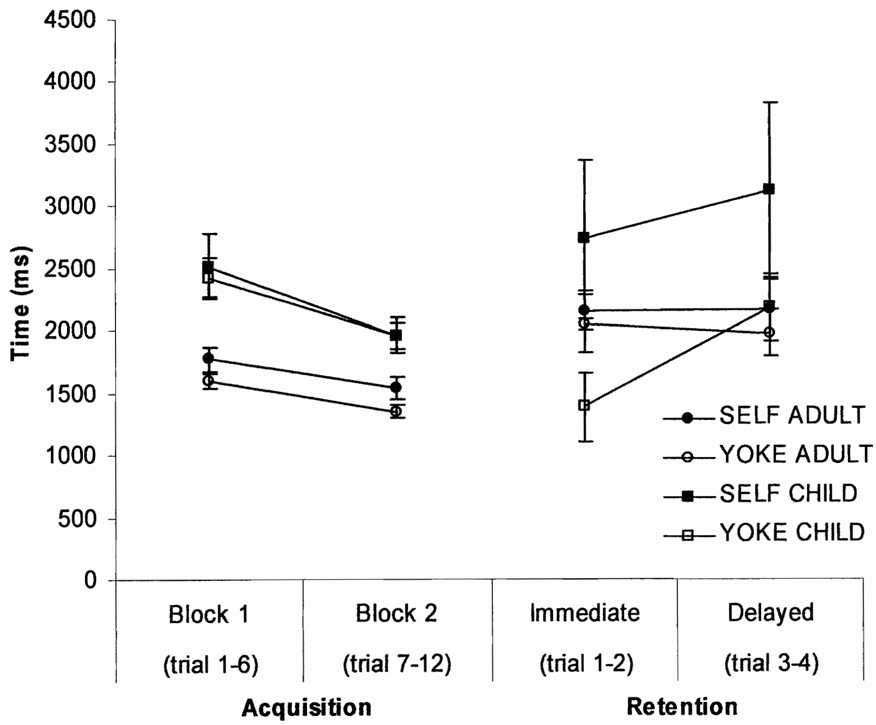
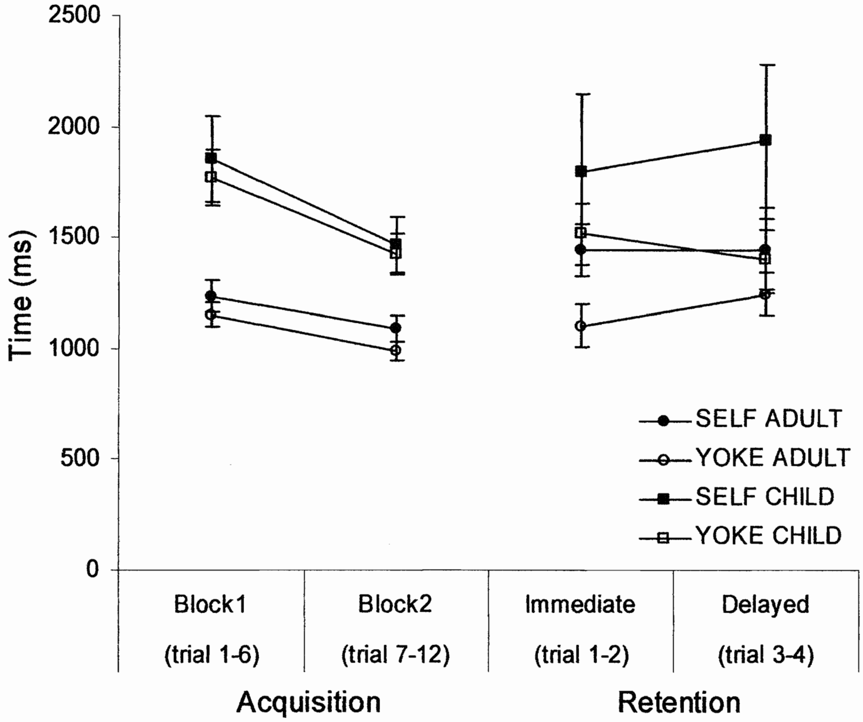

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Proportion Recall Success
SELF ADULT
YOKE ADULT
SELF CHILD
YOKE CHILD
Block 1
(trial 1-6)
Block 2
(trial 7-12)
Immediate
(trial 1-2)
Delayed
(trial 3-4)
Acquisition
Retention

Figure 4.



4500
4000
3500
3000
2500
2000
1500
1000
500
0
Time (ms)
SELF ADULT
YOKE ADULT
SELF CHILD
YOKE CHILD
Block 1
(trial 1-6)
Block 2
(trial 7-12)
Immediate
(trial 1-2)
Delayed
(trial 3-4)
Acquisition
Retention


Figure 5.



2500
2000
1500
1000
500
0
Time (ms)
SELF ADULT
YOKE ADULT
SELF CHILD
YOKE CHILD
Block1
(trial 1-6)
Block2
(trial 7-12)
Immediate
(trial 1-2)
Delayed
(trial 3-4)
Acquisition
Retention


Figure 6.

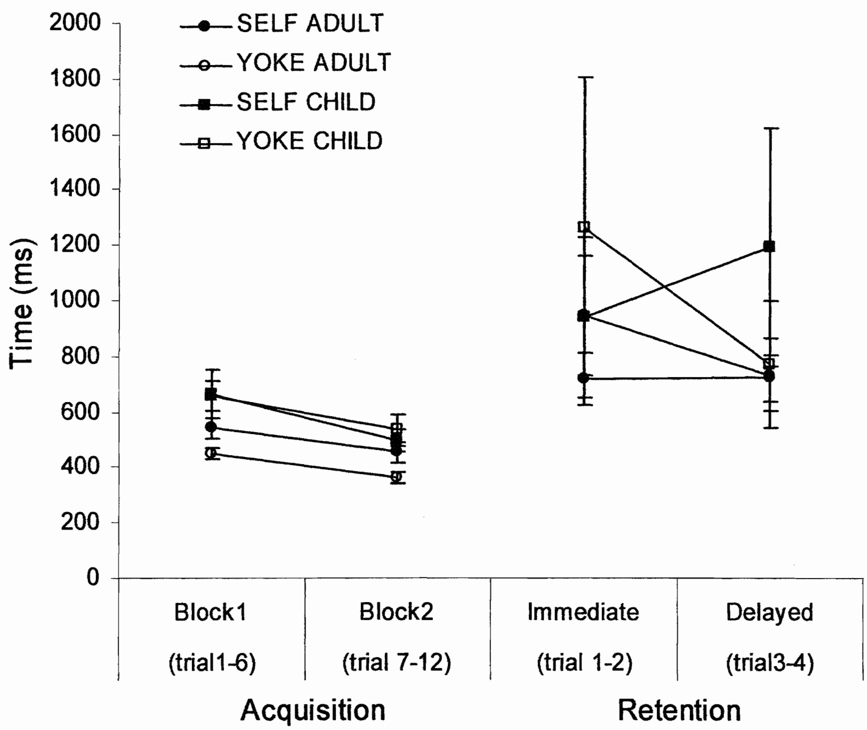

2000
1800
1600
1400
1200
1000
800
600
400
200
0
Time (ms)
SELF ADULT
YOKE ADULT
SELF CHILD
YOKE CHILD
Block1
(trial1-6)
Block2
(trial 7-12)
Immediate
(trial 1-2)
Delayed
(trial3-4)
Acquisition
Retention

Figure 7.

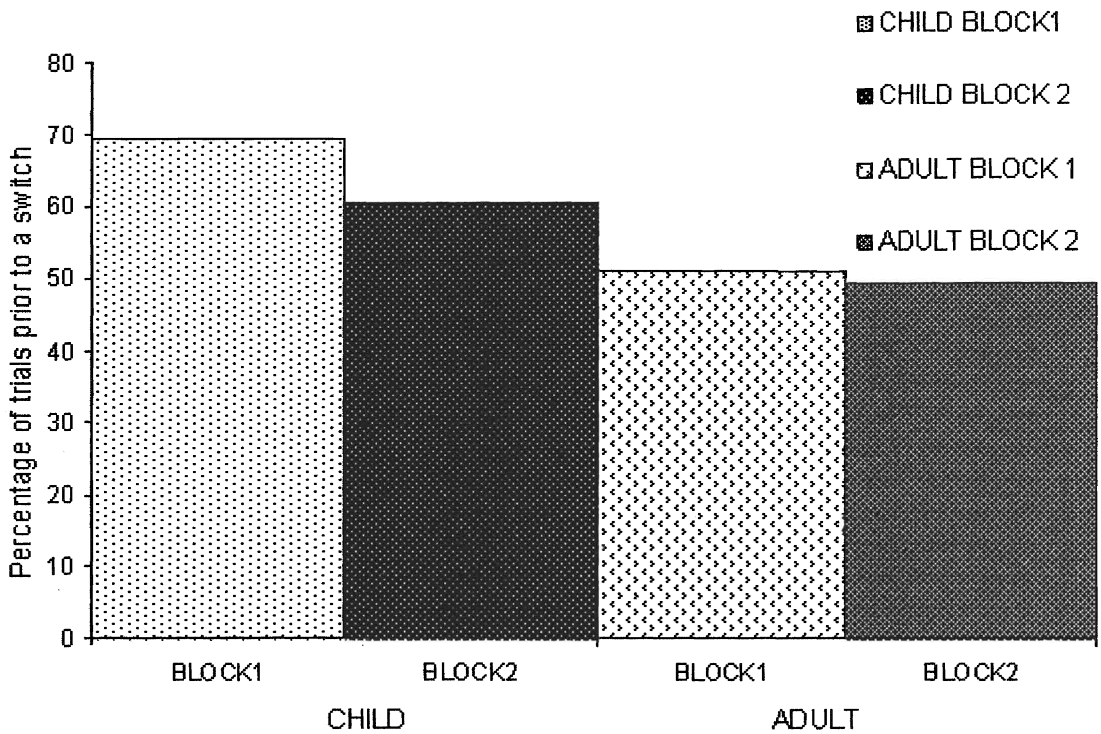

CHILD BLOCK1
CHILD BLOCK 2
ADULT BLOCK 1
ADULT BLOCK 2
Percentage of trials prior to a switch
80
70
60
50
40
30
20
10
0
BLOCK1
BLOCK2
BLOCK1
BLOCK2
CHILD
ADULT

Figure 8.

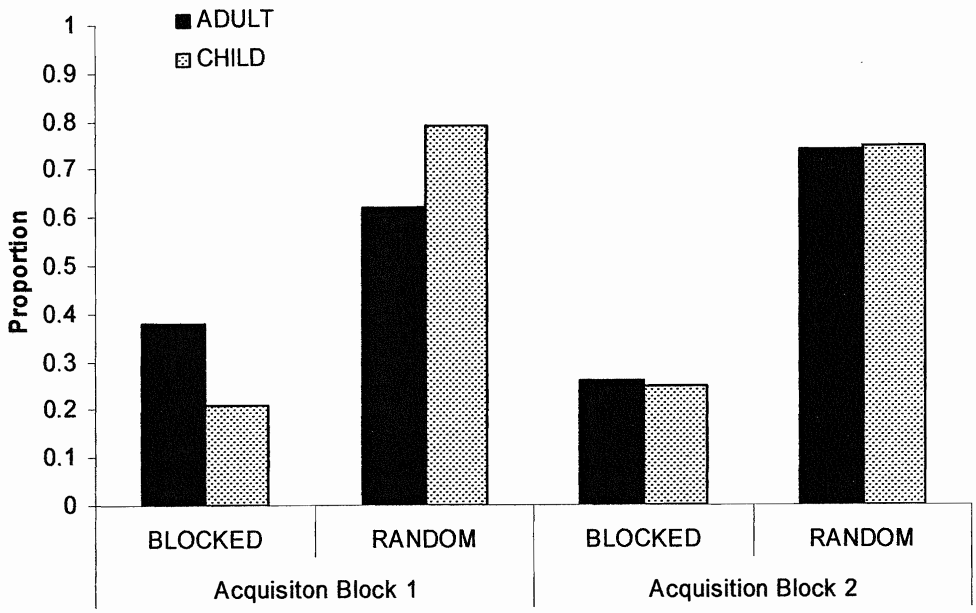

ADULT
CHILD
Proportion
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
BLOCKED
RANDOM
BLOCKED
RANDOM
Acquisiton Block 1
Acquisition Block 2

Figure 9.

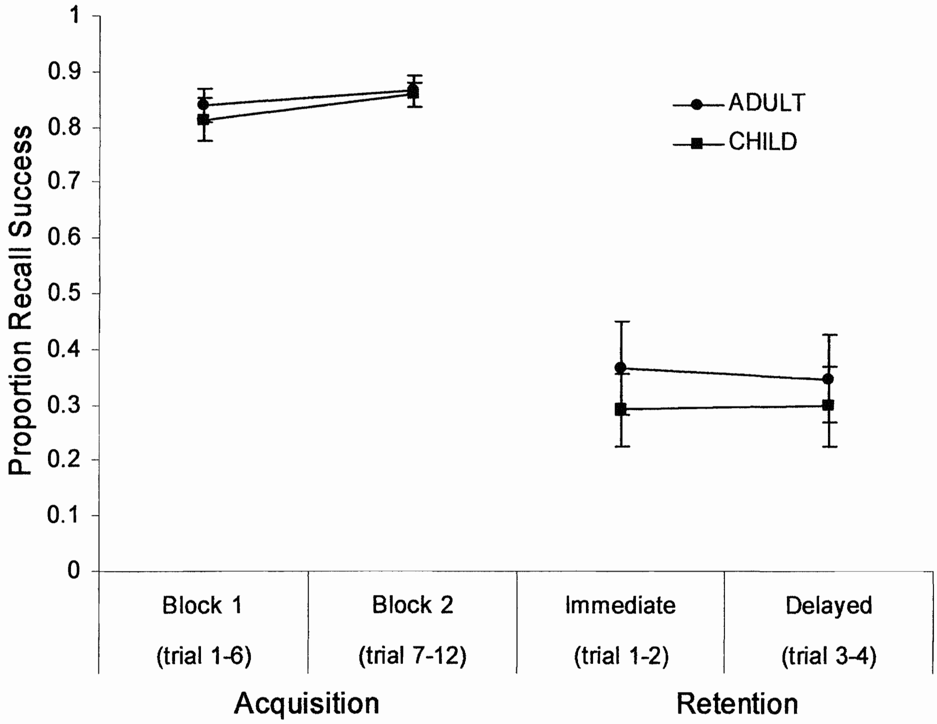

Proportion Recall Success
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ADULT
CHILD
Block 1
(trial 1-6)
Block 2
(trial 7-12)
Immediate
(trial 1-2)
Delayed
(trial 3-4)
Acquisition
Retention

Figure 10.

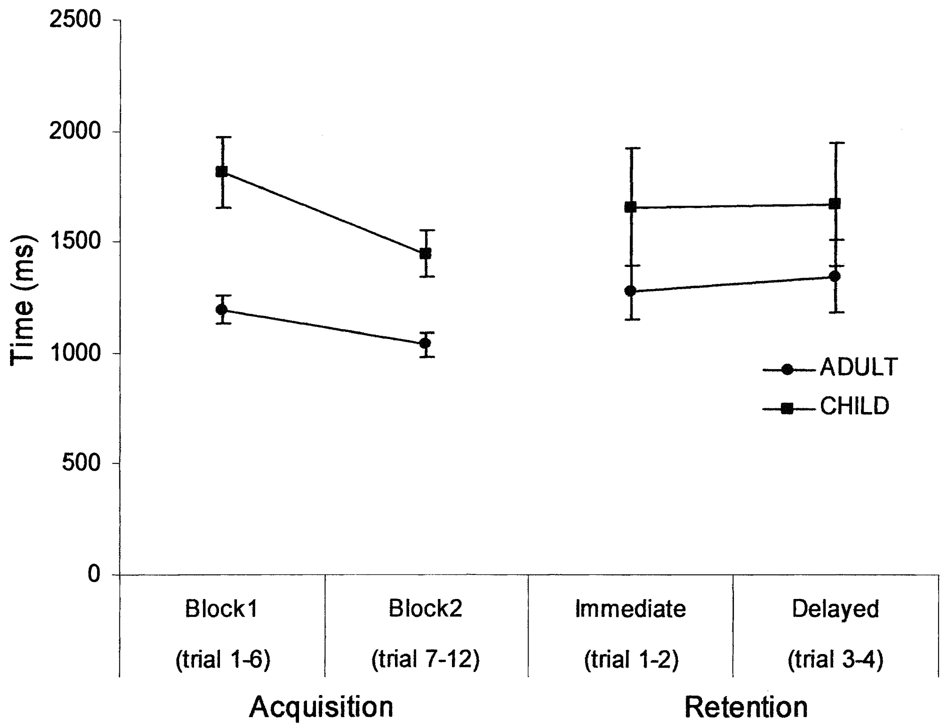

2500
2000
1500
1000
500
0
Time (ms)
ADULT
CHILD
Block1
(trial 1-6)
Block2
(trial 7-12)
Immediate
(trial 1-2)
Delayed
(trial 3-4)
Acquisition
Retention

Figure 11.

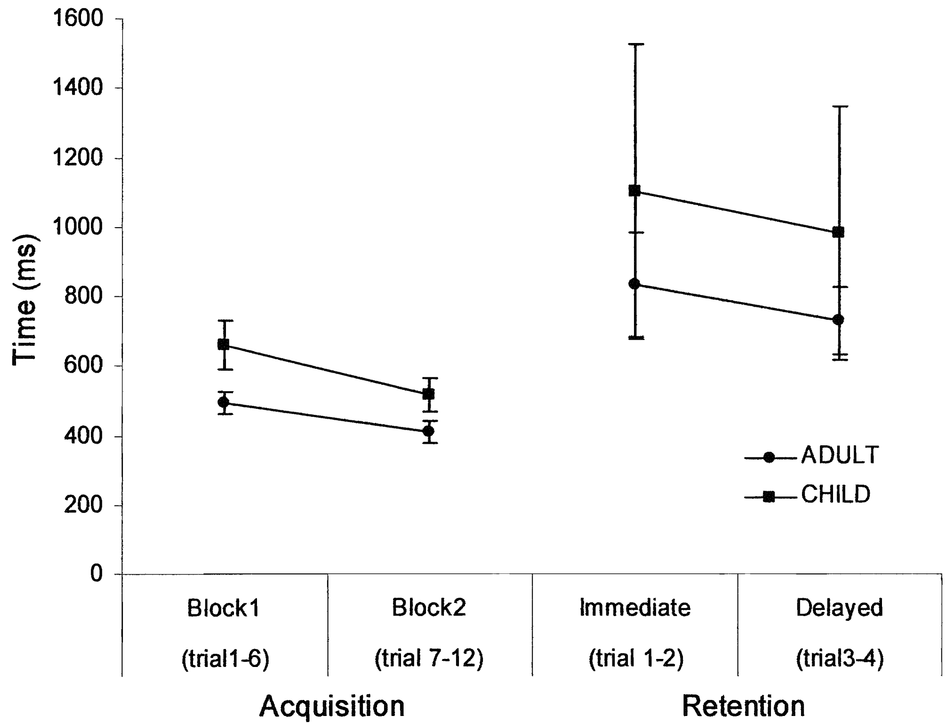

1600
1400
1200
1000
800
600
400
200
0
Time (ms)
ADULT
CHILD
Block1
(trial1-6)
Block2
(trial 7-12)
Immediate
(trial 1-2)
Delayed
(trial3-4)
Acquisition
Retention

Figure 12.

Table Captions

Table 1. Descriptive characteristics of participants in the CHILD-SELF, CHILD-YOKE, ADULT-SELF, ADULT-YOKE groups.

| | Number of participants | | Age of participants (years) | | |
|---|---|---|---|---|---|
| Condition | Male | Female | Mean | SD | Range |
| SELF ADULT | 4 | 8 | 22.6 | 2.4 | 18-25 |
| YOKE ADULT | 6 | 6 | 21.5 | 2.1 | 18-25 |
| SELF CHILD | 5 | 7 | 12.8 | 2.3 | 8-15 |
| YOKE CHILD | 4 | 8 | 11.5 | 1.8 | 9-15 |

Table 1.

Reference List

Adam, J. J., Parthoens, S. & Pratt, Jay. (2006). Distinct mechanisms for planning key press and reaching responses: A developmental study. *Human Movement Science*, 25, 293-309.

Alberet, J.M. & Thon,B. (1998). Differential effects of task complexity on contextual interference in a drawing task. *Acta Psychologica(Amst.)* 100, 9-24.

Battig, W. F. (1972). Intratask interference as a source of facilitation in transfer and retention. In R. F. Thompson & J. F. Voss (Eds.), *Topics in learning and performance* (pp. 131–159). New York: Academic Press.

Boekaerts, M. (1997). Self-regulated learning: A new concept embraced by researchers, policy makers, educators, teachers and students. *Learning and Instruction*, 7, 161-186.

Boswell, S. L., Sanders, B. & Young, S. J., (1974). The effects of exposure duration and practice on the immediate memory spans of children and adults. *Journal of Experimental and Child Psychology,* 17, 167-176.

Bouwien, C. M., Smits-Engelsman, Sugden, D. & Duysens, J., (2006). Developmental trends in speed accuracy trade-off in 6-10-year-old children performing rapid reciprocal and discrete aiming movements. *Human Movement Science*, 25, 37-49.

Chiviacowsky, S. & Wulf, G. (2002). Self-controlled feedback: does it enhance learning because performers get feedback when they need it? *Research Quarterly for Exercise and Sport*, 73, 408-415.

Chiviacowsky, S. & Wulf, G. (2005). Self-controlled feedback is effective if it is based on the learner's performance. *Research Quarterly for Exercise and Sport* 76, 42-48.

Chiviacowsky, S., Wulf, G., Laroque de Medeiros, F., Kaefer, A. & Tani, G., (2008). Learning benefits of self-controlled knowledge of results in 10-year-old children. *Research Quarterly for Exercise and Sport,* 79, 405-410.

Chiviacowsky, S., Wulf, G., Laroque de Medeiros, F., Kaefer, A. & Wally, R. (2008). Self-controlled feedback in 10-year-old children: Higher feedback frequencies enhance learning. *Research Quarterly for Exercise and Sport,* 79, 122-127.

Ferrari, M. (1996). Observing the observer: self-regulation in the observational learning of motor skills. *Developmental Review*, 16, 203-240

Guadagnoli, M. A. & Lee, T. D. (2004). Challenge point: a framework for conceptualizing the effects of various practice conditions in motor learning. *Journal of Motor Behaviour*, 36, 212-224.

Hartman, J. M. (2007). Self-controlled use of a perceived physical assistance device during a balancing task. *Perceptual and Motor Skills*, 104, 1005-1016.

Hiew, C, (1977). Sequence effects in rule learning and conceptual generalization. *American Journal of Psychology*, 90, 207-18

Janelle, C. M., Barba, D. A., Frehlich, S. G., Tennant, L. K., & Cauraugh, J. H. (1997). Maximizing performance feedback effectiveness through videotape replay and a self-controlled learning environment. *Research Quarterly for Exercise and Sport*, 68, 269-279.

Janelle, C. M., Kim, J., & Singer, R. N. (1995). Subject-controlled performance feedback and learning of a closed motor skill. *Perceptual and Motor Skills*, 81, 627-634.

Jarus, T. & Goverover, Y. (1999). Effects of contextual interference and age on acquisition, retention, and transfer of motor skill. *Perceptual and Motor Skills*, 88, 437-447.

Jarus, T. & Gutman, T. (2001). Effects of cognitive processes and task complexity on acquisition, retention, and transfer of motor skills. *Canadian Journal of Occupational Therapy*, 68, 280-289.

Keetch, K. M. & Lee, T. D. (2007). The effect of self-regulated and experimenter-imposed practice schedules on motor learning for tasks of varying difficulty. *Research Quarterly for Exercise and Sport*, 78, 476-486.

Kilduski, N.C. & Rice, M.S. (2003) Qualitative and quantitative knowledge of results: effects on motor learning. *American Journal of Occupational Therapy*, 57, 329-336.

Lee, T.D. & Magill, R. A. (1983). The locus of contextual interference in motor-skill acquisition. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 9, 730-746.

Lee, T.D.& Magill, R. A. (1985). Can forgetting facilitate skill acquisition? In D. Goodman, R. B. Wilberg & I. M. Franks (Eds.), *Differing perspectives on motor memory. Learning and control* (pp. 3-22). Amsterdam: Elsevier.

Lee, T. D., Wishart, L.R., Cunningham, S. &, Carnahan, H. (1997). Modeled timing information during random practice eliminates the contextual interference effect. *Research Quarterly for Exercise and Sport*, 68, 100-105.

Lee, T. D., Swinnen, S. P., & Serrien, D. J. (1994). Cognitive effort and motor learning. *Quest*, 46, 328-344.

Lodico, M. G., Ghatala, E. S., Levin, J. R., Pressley, M., & Bell, J. A. (1983). The effects of strategy-monitoring training on children's selection of effective memory strategies. *Journal of Experimental Child Psychology*, 35, 263-277.

Magill, RA (2004). Motor learning and control: Concepts and applications (7th ed.). Boston: McGraw-Hill.

Magill, RA. & Hall, KG., (1990). A review of the contextual interference effect in motor skill acquisition. *Human Movement Science*, 9, 241-289.

McCombs ML. (1989) Self-regulated learning and achievement: a phenomenological view. In: Zimmerman BJ, Schunk DH, editors. Self-regulated learning and academic achievement theory, research, and practice: progress in cognitive development research. New York: Springer-Verlag;. p. 51–82.

Nair, M. & Bunker, L. K. (2000). Effects of three practice schedules on the learning of field hockey skills in fourth and fifth graders. *Research Quarterly for Exercise and Sport*, 71.

Olivier, I., Ripoll, H., Audiffren, M. (1997). Age differences in using precued information to preprogram interception of a ball. *Perceptual and Motor Skills*, 85, 123-127.

Pollock, B. J. & Lee, T. D. (1997). Dissociated contextual interference effects in children and adults. *Perceptual and Motor Skills*, 84, 851-858.

Schmidt R.A., & Lee T. D., (2005). Motor Control and Learning A Behavioral Emphasis 4th Edition.

Shea, J. B. & Morgan, R. L. (1979). Contextual interference effects of the acquisition, retention and transfer of a motor skill. *Journal of Experimental Psychology: Human Learning and Memory*, 5, 179-187.

Ste-Marie, D. M., Clark, S. E., Findlay, L. C., & Latimer, A. E. (2004). High levels of contextual interference enhance handwriting skill acquisition. *Journal of Motor Behaviour*, 36, 115-126.

Sullivan, K. J., Kantak, S. S. & Burtner. P.A. (2008). Motor learning in children: feedback effects on skill acquisition. *Physical Therapy*, 88, 720-732

Thomas, J. R., Yan, J. H., & Stelmach, G. E. (2000). Movement substructures change as a function of practice in children and adults. *Journal of Experimental Child Psychology*, 75, 228-244.

Titzer, R., Shea, J., & Romack, J. (1993). The effect of learner control on the acquisition and retention of a motor skill. *Journal of Sport & Exercise Psychology*, 15(Supplement).

Vera, J. G. & Montilla, M. M. (2003). Practice schedule and acquisition, retention, and transfer of a throwing task in 6-yr.-old children. *Perceptual and Motor Skills*, 96, 1015-1024.

Walker, M., Brakefield, T., Morgan, A., Hobson, R. & Stickgold, R.(2002). Practice with sleep makes perfect sleep-dependent motor skill learning. *Neuron*, 35, 205-211

Watkins D. (1984) Students' perceptions of factors influencing tertiary learning. *Higher Educ Res Dev* 3, 33–50.

Wilde, H., Magnuson, C. & Shea, C.H.(2005). Random and blocked practice of movement sequences: Differential effects on response structure and movement speed. *Research Quarterly for Exercise and Sport*, 76, 416-425

Winne, P. H. (1995). Inherent details in self-regulated learning. *Educational Psychologist,* 30, 173-187.

Wrisberg, C. A. & Pein, R. L. (2002). Note on learners' control of the frequency of model presentation during skill acquisition. *Perceptual and Motor Skills*, 94, 792-794.

Wu, W. & Magill, R. A. (2004). To dictate or not: The exploration of a self-regulated practice schedule. *Journal of Sport & Exercise Psychology,* 26(Supplement), 202.

Wu, W. F. W. (2007). Self-control of learning multiple motor skills. Louisiana State University and Agricultural and Mechanical College.

Wulf, G. (2007). Self-controlled practice enhances motor learning: implications for physiotherapy. *Physiotherapy*, 93, 96-101

Wulf, G. (1991). The effect of type of practice on motor learning in children. *Applied Cognitive Pyschology,* 5, 123-134.

Wulf, G., Clauss, A., Shea, C. H., & Whitacre, C. A. (2001). Benefits of self-control in dyad practice. *Research Quarterly for Exercise and Sport*, 72, 299-303.

Wulf, G., Raupach, M., & Pfeiffer, F. (2003). Self-controlled observational practice enhances learning. *Journal of Sport and Exercise Psychology*, 25(Supplement), 142.

Wulf, G. & Toole, T. (1999). Physical assistance devices in complex motor skill learning: Benefits of a self-controlled practice schedule. *Research Quarterly forExercise and Sport,* 70, 265-272.

Zimmerman, B. J. (1985). The development of "intrinsic" motivation: A social learning analysis. *Annals of Child Development*, 2, 117-160.

Zimmerman, B. J. & Martinez-Pons, M. (1990). Student differences in self-regulated learning: Relating grades, sex, and giftedness to self-efficacy and strategy use. *Journal of Educational Psychology*, 82, 51-59.

## Appendix A1

***Analysis of Variance for Recall Success in Acquisition***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | Between subjects | | | |
| Intercept | 1 | 6204.24 | 68.29 | .00 |
| Age | 1 | .57 | .006 | .46 |
| Practice Condition | 1 | 2.26 | .025 | .14 |
| Age x Practice Condition | 1 | .60 | .007 | .44 |
| Error | 44 | | .011 | |
| | Within subjects | | | |
| Block | 1 | 2.69 | .029 | .11 |
| Block x Age | 1 | .19 | .002 | .67 |
| Block x Practice Condition | 1 | .11 | .001 | .74 |
| Block x Age x Practice Condition | 1 | 1.18 | .013 | .28 |
| Error (block) | 44 | | | |

* $p < .05$.

**Appendix A2**

***Analysis of Variance for Recall Success in Retention***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | | Between subjects | | |
| Intercept | 1 | 93.78 | .15 | .00 |
| Age | 1 | 1.34 | .07 | .25 |
| Practice Condition | 1 | 4.56* | .24 | .038 |
| Age x Practice Condition | 1 | 2.58 | .13 | .12 |
| Error | 44 | | .011 | |

* $p < .05$.

## Appendix A3

*Analysis of Variance for Total Time in Acquisition*

| Source | *df* | F | η | p |
|---|---|---|---|---|
| Between subjects | | | | |
| Intercept | 1 | 867.11 | 3.441E8 | 0.0 |
| Age | 1 | 25.40* | 1.008E 7 | .0.0 |
| Practice Condition | 1 | .80 | 318079.81 | .38 |
| Age x Practice Condition | 1 | .28 | 111992.1 | .60 |
| Error | 44 | | 396844.59 | |
| Within subjects | | | | |
| Block | 1 | 67.31* | 3397724.55 | 0.0 |
| Block x Age | 1 | 8.52* | 429844.80 | .006 |
| Block x Practice Condition | 1 | .11 | 5554.13 | .74 |
| Block x Age x Practice Condition | 1 | .283 | 14281.52 | .60 |
| Error (block) | 44 | | 50481.98 | |

* $p < .05$.

## Appendix A4

***Analysis of Variance for Total Time in Retention***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | Between subjects | | | |
| Intercept | 1 | 93.1 | 1.965E8 | .51 |
| Age | 1 | .13 | 315007.3 | .78 |
| Practice Condition | 1 | 1.72 | 4290587.73 | .42 |
| Age x Practice Condition | 1 | 2.40 | 2494712.0 | .13 |
| Error | 35 | | 1.043E6 | |

* p < .05.

## Appendix A5

***Analysis of Variance for Movement Time in Acquisition***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | | Between subjects | | |
| Intercept | 1 | 725.45 | 1.81 | .00 |
| Age | 1 | 25.26* | 6300360.80 | .00 |
| Practice Condition | 1 | .58 | 143531.30 | .14 |
| Age x Practice Condition | 1 | .021 | .5310.83 | .89 |
| Error | 44 | | .011 | |
| | | Within subjects | | |
| Block | 1 | 67.71* | 1618184.22 | .00 |
| Block x Age | 1 | 10.915* | 260852.33 | .002 |
| Block x Practice Condition | 1 | .016 | 389.01 | .90 |
| Block x Age x Practice Condition | 1 | .178 | 4251.24 | .68 |
| Error (block) | 44 | | 23897.57 | |

* $p < .05$.

## Appendix A6

***Analysis of Variance for Movement Time in Retention***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | | Between subjects | | |
| Intercept | 1 | 242.53 | 9.19 | .00 |
| Age | 1 | 2.81 | 1063820.73 | .10 |
| Practice Condition | 1 | 3.07 | 1164662.45 | .09 |
| Age x Practice Condition | 1 | .01 | 3800.73 | .92 |
| Error | 36 | | 378965.42 | |

* $p < .05$.

## Appendix A7

***Analysis of Variance for Reaction Time in Acquisition***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | | Between subjects | | |
| Intercept | 1 | 591.68 | 2.60 | .00 |
| Age | 1 | 10.06* | 441881.42 | .003 |
| Practice Condition | 1 | .78 | 34273.26 | .382 |
| Age x Practice Condition | 1 | 1.56 | 68527.06 | .22 |
| Error | 44 | | 43938.20 | |
| | | Within subjects | | |
| Block | 1 | 29.88* | 326284.87 | .00 |
| Block x Age | 1 | 1.92 | 20992.66 | .173 |
| Block x Practice Condition | 1 | .275 | 3003.35 | .60 |
| Block x Age x Practice Condition | 1 | .27 | 2948.91 | .61 |
| Error (block) | 44 | | 10920.81 | |

* $p < .05$.

## Appendix A8

***Analysis of Variance for Reaction Time in Retention***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | | Between subjects | | |
| Intercept | 1 | 67.38 | 3.40 | .00 |
| Age | 1 | 1.32 | 667899.27 | .26 |
| Practice Condition | 1 | .00 | 2.67 | 1.0 |
| Age x Practice Condition | 1 | .40 | 19920.93 | .53 |
| Error | 36 | | 504884.53 | |

* p < .05.

## Appendix A9

*Analysis of Variance for Switching in Acquisition for SELF groups*

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | Between subjects | | | |
| Intercept | 1 | 91.38 | 159464.52 | .00 |
| Age | 1 | 1.51 | 2632.92 | .232 |
| Error | 22 | | 1745.016 | |
| | Within Subjects | | | |
| Block | 1 | .75 | 311.31 | .40 |
| Block x Age | 1 | .40 | 164.65 | .53 |
| Error (block) | 22 | | 413.22 | |

* $p < .05$.

**Appendix A10**

***Analysis of Variance for Switch Status and Recall Success in Acquisition***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | | Between subjects | | |
| Intercept | 1 | 4055.38 | 696208.55 | .00 |
| Age | 1 | .79 | 135.43 | .38 |
| Practice Condition | 1 | 1.96 | 336.94 | .17 |
| Age x Practice Condition | 1 | 1.74 | 298.89 | .19 |
| Error | 44 | | 171.68 | |
| | | Within Subjects | | |
| Block | 1 | .01 | 1.33 | .95 |
| Block x Age | 1 | .04 | 6.64 | .85 |
| Block x Practice Condition | 1 | .00 | .72 | .95 |
| Block x Age x Practice Condition | 1 | .01 | 2.52 | .91 |
| Error (block) | 44 | | 180.63 | |

* $p < .05$.

## Appendix A11

***Analysis of Variance for Switch Status and Movement Time in Acquisition***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | Between subjects | | | |
| Intercept | 1 | 523.40 | 1.83 | .00 |
| Age | 1 | 20.75* | 7247561.55 | .00 |
| Practice Condition | 1 | .029 | 138493.42 | .53 |
| Age x Practice Condition | 1 | .029 | 10139.48 | .87 |
| Error | 44 | | 349275.21 | |
| | Within Subjects | | | |
| Block | 1 | .02 | 554.90 | .89 |
| Block x Age | 1 | .25 | 7078.31 | .62 |
| Block x Practice Condition | 1 | .76 | 21600.99 | .39 |
| Block x Age x Practice Condition | 1 | .53 | 15239.44 | .47 |
| Error (block) | 44 | | 28552.67 | |

* $p < .05$.

## Appendix A12

***Analysis of Variance for Switch Status and Reaction Time in Acquisition***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | | Between subjects | | |
| Intercept | 1 | 393.49 | 2.61 | .00 |
| Age | 1 | 7.27* | 482235.69 | .01 |
| Practice Condition | 1 | .65 | 42790.30 | .43 |
| Age x Practice Condition | 1 | 1.71 | 113654.27 | .20 |
| Error | 44 | | 66310.69 | |
| | | Within Subjects | | |
| Block | 1 | .10 | 860.09 | .76 |
| Block x Age | 1 | 1.14 | 10201.75 | .29 |
| Block x Practice Condition | 1 | .10 | 902.19 | .75 |
| Block x Age x Practice Condition | 1 | .01 | 58.73 | .94 |
| Error (block) | 44 | | 8961.23 | |

$* p < .05$.

## Appendix A13

***Analysis of Variance for Practice Schedule Type in Acquisition***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | | Between subjects | | |
| Intercept | 1 | 99.02 | 24.0 | .00 |
| Age | 1 | 0.0 | 0.0 | 1.0 |
| Practice Type | 1 | 20.18 | 4.90 | .00 |
| Age x Practice Type | 1 | 1.71 | 113654.27 | .20 |
| Error | 44 | | 66310.69 | |
| | | Within Subjects | | |
| Block | 1 | 0.0 | 0.0 | 1.0 |
| Block x Age | 1 | 0.0 | 0.0 | 1.0 |
| Block x Practice Type | 1 | .94 | .03 | .34 |
| Block x Age x Practice Type | 1 | .81 | .20 | .04 |
| Error (block) | 44 | | .24 | |

* $p < .05$.

## Appendix A14

***Analysis of Variance for Age and Recall Success in Acquisition***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | | Between subjects | | |
| Intercept | 1 | 6090.43 | 68.29 | .00 |
| Age | 1 | .56 | .006 | .46 |
| Error | 46 | | .011 | |
| | | Within subjects | | |
| Block | 1 | 2.73 | .029 | .11 |
| Block x Age | 1 | .19 | .002 | .67 |
| Error (block) | 46 | | .011 | |

## Appendix A15

***Analysis of Variance for Age and Recall Success in Retention***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | Between subjects | | | |
| Intercept | | 84.35 | 4.87 | .00 |
| Age | 1 | 1.21 | .07 | .28 |
| Error | 46 | | .058 | |

## Appendix A16

*Analysis of Variance for Age and Movement Time in Acquisition*

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | Between subjects | | | |
| Intercept | 1 | 748.27 | 1.809E8 | .00 |
| Age | 1 | 26.06* | 6300360.796 | .00 |
| Error | 46 | | 241808.955 | |
| | Within subjects | | | |
| Block | 1 | 70.48* | 1618184.221 | .00 |
| Block x Age | 1 | 11.36* | 260852.332 | .002 |
| Error (block) | 46 | | 22959.421 | |

**Appendix A17**

***Analysis of Variance for Age and Movement Time in Retention***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | Between subjects | | | |
| Intercept | | 236.18 | 9.203E7 | .00 |
| Age | 1 | 2.46 | 957279.323 | .13 |
| Error | 38 | | 389670.335 | |

## Appendix A18

***Analysis of Variance for Age and Reaction Time in Acquisition***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | | Between subjects | | |
| Intercept | 1 | 587.34 | 2.600E7 | .00 |
| Age | 1 | 9.98 | 441881.420 | .003 |
| Error | 46 | | 44262.636 | |
| | | Within subjects | | |
| Block | 1 | 30.85 | 326284.371 | .00 |
| Block x Age | 1 | .199 | 20992.664 | .17 |
| Error (block) | 46 | | 10575.388 | |

## Appendix A19

***Analysis of Variance for Age and Reaction Time in Retention***

| Source | *df* | F | η | p |
|---|---|---|---|---|
| | | Between subjects | | |
| Intercept | | 69.98 | 3.384E7 | .00 |
| Age | 1 | 1.38 | 667896.667 | .25 |
| Error | 38 | | 483569.247 | |

**Appendix A20**

***Descriptive Statistics for Recall Success in Acquisition***

| Experimental group | Mean | SD |
|---|---|---|
| | Block 1 | |
| CHILD | | |
| SELF a | .77 | .17 |
| YOKE a | .85 | .08 |
| TOTAL b | .81 | .14 |
| ADULT | | |
| SELF a | .84 | .12 |
| YOKE a | .84 | .08 |
| TOTAL b | .84 | .10 |
| TOTAL | | |
| SELF a | .81 | .15 |
| YOKE a | .85 | .08 |
| TOTAL b | .83 | .12 |
| | Block 2 | |
| CHILD | | |
| SELF a | .85 | .08 |
| YOKE a | .87 | .08 |
| TOTAL b | .86 | .08 |
| ADULT | | |

| Experimental group | Mean | SD |
|---|---|---|
| SELF a | .85 | .09 |
| YOKE a | .88 | .10 |
| TOTAL b | .86 | .09 |
| TOTAL | | |
| SELF a | .85 | .08 |
| YOKE a | .87 | .09 |
| TOTAL | .86 | .09 |

a n= 12, b n= 24

## Appendix A21

***Descriptive Statistics for Recall Success in Retention***

| Experimental group | Mean | SD |
|---|---|---|
| CHILD | | |
| SELF a | .30 | .22 |
| YOKE a | .26 | .22 |
| TOTAL b | .28 | .21 |
| ADULT | | |
| SELF a | .48 | .23 |
| YOKE a | .23 | .19 |
| TOTAL b | .32 | .24 |
| TOTAL | | |
| SELF a | .39 | .26 |
| YOKE a | .25 | .12 |
| TOTAL b | .32 | .24 |

a n= 12, b n= 24

## Appendix A22

***Descriptive Statistics for Total Time in Acquisition***

| Experimental group | Mean | SD |
|---|---|---|
| | Block 1 | |
| CHILD | | |
| SELF a | 2515.54 | 894.96 |
| YOKE a | 2429.12 | 547.70 |
| TOTAL b | 2472.33 | 726.96 |
| ADULT | | |
| SELF a | 1777.58 | 344.56 |
| YOKE a | 1603.32 | 214.96 |
| TOTAL b | 1690.45 | 674.97 |
| TOTAL | | |
| SELF a | 2146.56 | 760.70 |
| YOKE a | 2016.22 | 586.10 |
| TOTAL b | 2081.39 | 674.97 |
| | Block 2 | |
| CHILD | | |
| SELF a | 1965.85 | 514.94 |
| YOKE a | 1958.64 | 380.72 |
| TOTAL b | 1962.24 | 442.89 |
| ADULT | | |

| Experimental group | Mean | SD |
|---|---|---|
| SELF a | 1544.33 | 303.56 |
| YOKE a | 1351.71 | 167.31 |
| TOTAL b | 1448.02 | 259.11 |
| TOTAL | | |
| SELF a | 1755.09 | 466.10 |
| YOKE a | 1655.18 | 422.85 |
| TOTAL | 1705.13 | 443.12 |

a n= 12, b n= 24

## Appendix A23

***Descriptive Statistics for Total Time in Retention***

| Experimental group | Mean | SD |
|---|---|---|
| CHILD | | |
| SELF b | 2929.38 | 1.81E3 |
| YOKE a | 1756.08 | 567.62 |
| TOTAL d | 2311.85 | 1.41E3 |
| ADULT | | |
| SELF c | 2241.40 | 694.49 |
| YOKE a | 2083.31 | 560.03 |
| TOTAL f | 2170.26 | 626.44 |
| TOTAL | | |
| SELF e | 2550.99 | 1.33E3 |
| YOKE e | 1911.08 | 573.30 |
| TOTAL | 2239.23 | 1.1E3 |

a n = 10, b n = 9, c n = 11, d n = 19, e n= 20, f n= 21

**Appendix A24**

***Descriptive Statistics for Movement Time in Acquisition***

| Experimental group | Mean | SD |
|---|---|---|
| Block 1 | | |
| CHILD | | |
| SELF a | 1850.91 | 669.5 |
| YOKE a | 1771.12 | 431.90 |
| TOTAL b | 1811.01 | 552.47 |
| ADULT | | |
| SELF a | 1235.86 | 259.56 |
| YOKE a | 1152.93 | 190.48 |
| TOTAL b | 1194.40 | 226.64 |
| TOTAL | | |
| SELF a | 1543.38 | 587.59 |
| YOKE a | 1462.02 | 454.16 |
| TOTAL b | 1502.70 | 521.13 |
| Block 2 | | |
| CHILD | | |
| SELF a | 1469.66 | 437.50 |
| YOKE a | 1424.53 | 312.61 |
| TOTAL b | 1447.10 | 372.57 |
| ADULT | | |

| Experimental group | Mean | SD |
|---|---|---|
| SELF a | 1089.73 | 212.34 |
| YOKE a | 988.24 | 143.78 |
| TOTAL b | 1038.99 | 184.77 |
| TOTAL | | |
| SELF a | 1279.70 | 388.28 |
| YOKE a | 1279.70 | 326.01 |
| TOTAL | 1243.04 | 356.59 |

a n= 12, b n= 24

## Appendix A25

***Descriptive Statistics for Movement Time in Retention***

| Experimental group | Mean | SD |
|---|---|---|
| CHILD | | |
| SELF b | 1863.98 | 1.0 |
| YOKE a | 1502.30 | 391.64 |
| TOTAL d | 1673.62 | 750.77 |
| ADULT | | |
| SELF c | 1517.45 | 599.98 |
| YOKE a | 1194.86 | 239.65 |
| TOTAL f | 1363.83 | 482.79 |
| TOTAL | | |
| SELF e | 1673.39 | 805.89 |
| YOKE e | 1348.58 | 353.18 |
| TOTAL | 1510.98 | 635.79 |

a n = 10, b n = 9, c n = 11, d n = 19, e n= 20, f n= 21

## Appendix A26

***Descriptive Statistics for Reaction Time in Acquisition***

| Experimental group | Mean | SD |
|---|---|---|
| | Block 1 | |
| CHILD | | |
| SELF a | 664.63 | 296.67 |
| YOKE a | 658.01 | 184.66 |
| TOTAL b | 661.32 | 241.69 |
| ADULT | | |
| SELF a | 541.72 | 127.12 |
| YOKE a | 450.39 | 77.51 |
| TOTAL b | 496.05 | 113.04 |
| TOTAL | | |
| SELF a | 603.18 | 231.87 |
| YOKE a | 554.20 | 174.43 |
| TOTAL b | 578.69 | 204.48 |
| | Block 2 | |
| CHILD | | |
| SELF a | 496.19 | 129.62 |
| YOKE a | 534.10 | 195.92 |
| TOTAL b | 515.15 | 163.61 |
| ADULT | | |

| Experimental group | Mean | SD |
|---|---|---|
| SELF a | 454.59 | 123.87 |
| YOKE a | 363.47 | 68.02 |
| TOTAL b | 409.03 | 108.24 |
| TOTAL | | |
| SELF a | 475.39 | 125.80 |
| YOKE a | 448.79 | 167.83 |
| TOTAL | 462.09 | 147.34 |

a n= 12, b n= 24

## Appendix A27

***Descriptive Statistics for Reaction Time in Retention***

| Experimental group | Mean | SD |
|---|---|---|
| CHILD | | |
| SELF b | 1124.54 | 992.07 |
| YOKE a | 983.56 | 940.14 |
| TOTAL d | 1050.34 | 940.52 |
| ADULT | | |
| SELF c | 723.95 | 196.56 |
| YOKE a | 865.97 | 466.80 |
| TOTAL f | 791.58 | 350.22 |
| TOTAL | | |
| SELF e | 904.22 | 690.32 |
| YOKE e | 924.76 | 724.93 |
| TOTAL | 904.22 | 690.32 |

a n = 10, b n = 9, c n = 11, d n = 19, e n= 20, f n= 21

## Appendix A28

***Descriptive Statistics for Percent of Switch Trials***

| Experimental group | Mean | SD |
|---|---|---|
| | Block 1 | |
| CHILD | | |
| SELF a | 69.44 | 34.69 |
| ADULT | | |
| SELF a | 50.93 | 28.51 |
| TOTAL | | |
| TOTAL b | 60.19 | 32.46 |
| | Block 2 | |
| CHILD | | |
| SELF a | 60.65 | 36.81 |
| ADULT | | |
| SELF a | 49.54 | 30.75 |
| TOTAL | | |
| TOTAL | 55.09 | 33.65 |

## Appendix A29

***Descriptive Statistics for Recall Success Switch Trials***

| Experimental group | Mean | SD |
|---|---|---|
| Pre Switch | | |
| CHILD | | |
| SELF a | 82.81 | 18.95 |
| YOKE a | 89.59 | 9.36 |
| TOTAL b | 86.20 | 15.02 |
| ADULT | | |
| SELF a | 84.17 | 13.47 |
| YOKE a | 84.54 | 15.54 |
| TOTAL b | 84.35 | 14.22 |
| TOTAL | | |
| SELF a | 83.49 | 16.09 |
| YOKE a | 87.06 | 12.81 |
| TOTAL b | 85.28 | 14.50 |
| Non Pre Switch | | |
| CHILD | | |
| SELF a | 82.61 | 13.79 |
| YOKE a | 90.38 | 9.88 |
| TOTAL b | 86.49 | 12.38 |
| ADULT | | |

| Experimental group | Mean | SD |
|---|---|---|
| SELF a | 83.56 | 12.78 |
| YOKE a | 83.63 | 9.43 |
| TOTAL b | 83.59 | 10.98 |
| TOTAL | | |
| SELF a | 83.08 | 13.01 |
| YOKE a | 87.00 | 10.06 |
| TOTAL | 85.04 | 11.67 |

a n= 12, b n= 24

## Appendix A30

***Descriptive Statistics for Movement Time Switch Trials***

| Experimental group | Mean | SD |
|---|---|---|
| | Pre Switch | |
| CHILD | | |
| SELF a | 1648.64 | 553.71 |
| YOKE a | 1648.43 | 475.57 |
| TOTAL b | 1648.54 | 504.78 |
| ADULT | | |
| SELF a | 1162.04 | 237.34 |
| YOKE a | 1070.32 | 176.18 |
| TOTAL b | 1116.18 | 209.71 |
| TOTAL | | |
| SELF a | 1405.34 | 485.12 |
| YOKE a | 1359.38 | 458.47 |
| TOTAL b | 1382.36 | 467.51 |
| | Non Pre Switch | |
| CHILD | | |
| SELF a | 1716.21 | 822.02 |
| YOKE a | 1605.60 | 388.72 |
| TOTAL b | 1660.90 | 631.37 |

| ADULT | | |
|---|---|---|
| Experimental group | Mean | SD |
| SELF a | 1144.86 | 224.44 |
| YOKE a | 1043.54 | 118.24 |
| TOTAL b | 1094.20 | 182.91 |
| TOTAL | | |
| SELF a | 1430.53 | 657.59 |
| YOKE a | 1324.57 | 401.70 |
| TOTAL | 1377.55 | 541.70 |

a n= 12, b n= 24

## Appendix A31

***Descriptive Statistics for Reaction Time Switch Trials***

| Experimental group | Mean | SD |
|---|---|---|
| Pre Switch | | |
| CHILD | | |
| SELF a | 588.38 | 245.92 |
| YOKE a | 622.66 | 193.13 |
| TOTAL b | 605.52 | 216.95 |
| ADULT | | |
| SELF a | 496.39 | 138.07 |
| YOKE a | 389.92 | 83.03 |
| TOTAL b | 443.15 | 123.98 |
| TOTAL | | |
| SELF a | 542.38 | 200.62 |
| YOKE a | 506.29 | 187.80 |
| TOTAL b | 524.34 | 193.10 |
| Non Pre Switch | | |
| CHILD | | |
| SELF a | 569.47 | 285.00 |
| YOKE a | 588.36 | 260.41 |
| TOTAL b | 578.92 | 267.16 |
| ADULT | | |

| Experimental group | Mean | SD |
|---|---|---|
| SELF a | 515.59 | 153.59 |
| YOKE a | 399.98 | 68.78 |
| TOTAL b | 457.78 | 216.81 |
| TOTAL | | |
| SELF a | 542.53 | 225.58 |
| YOKE a | 494.17 | 209.65 |
| TOTAL | 518.35 | 216.81 |

a n= 12, b n= 24

## Appendix A32

***Descriptive Statistics for SELF Groups, Practice Type in Acquisition***

| Age and Type of Practice | Mean | SD |
|---|---|---|
| Block 1 | | |
| CHILD | | |
| BLOCKED-TYPE a | .21 | .40 |
| RANDOM-TYPE a | .79 | .40 |
| TOTAL b | .50 | .49 |
| ADULT | | |
| BLOCKED-TYPE a | .38 | .33 |
| RANDOM-TYPE a | .63 | .33 |
| TOTAL b | .50 | .34 |
| TOTAL | | |
| BLOCKED-TYPE a | .29 | .37 |
| RANDOM-TYPE a | .71 | .37 |
| TOTAL b | .50 | .42 |
| Block 2 | | |
| CHILD | | |
| BLOCKED-TYPE a | .25 | .39 |
| RANDOM-TYPE a | .75 | .39 |
| TOTAL b | .5 | .46 |
| ADULT | | |

| Age and Type of Practice | Mean | SD |
|---|---|---|
| BLOCKED-TYPE a | .26 | .37 |
| RANDOM-TYPE a | .74 | .37 |
| TOTAL b | .5 | .43 |
| TOTAL | | |
| BLOCKED-TYPE a | .26 | .37 |
| RANDOM-TYPE a | .74 | .37 |
| TOTAL b | .5 | .44 |

a n= 12, b n= 24

## Appendix A33

### *Barthel Index*

**Patient Name:** ____________________________

**Rater Name:** ____________________________

**Date:** ____________________________

**Activity Score**

**FEEDING**
0 = unable
5 = needs help cutting, spreading butter, etc., or requires modified diet
10 = independent ______

**BATHING**
0 = dependent
5 = independent (or in shower) ______

**GROOMING**
0 = needs to help with personal care
5 = independent face/hair/teeth/shaving (implements provided) ______

**DRESSING**
0 = dependent
5 = needs help but can do about half unaided
10 = independent (including buttons, zips, laces, etc.) ______

**BOWELS**
0 = incontinent (or needs to be given enemas)
5 = occasional accident
10 = continent ______

**BLADDER**
0 = incontinent, or catheterized and unable to manage alone
5 = occasional accident
10 = continent ______

**TOILET USE**
0 = dependent
5 = needs some help, but can do something alone
10 = independent (on and off, dressing, wiping) ______

**TRANSFERS (BED TO CHAIR AND BACK)**
0 = unable, no sitting balance
5 = major help (one or two people, physical), can sit
10 = minor help (verbal or physical)
15 = independent ______

**MOBILITY (ON LEVEL SURFACES)**
0 = immobile or < 50 yards
5 = wheelchair independent, including corners, > 50 yards
10 = walks with help of one person (verbal or physical) > 50 yards
15 = independent (but may use any aid; for example, stick) > 50 yards ______

**STAIRS**
0 = unable
5 = needs help (verbal, physical, carrying aid)
10 = independent ______

**TOTAL (0–100):** ______

**Appendix A34**

***An example of the colouring in a colouring book***

## Appendix A35

***Summary of instruction screens presented to participants at the beginning of acquisition***

1) The first screen welcomed the participant to the experiment.

2) The second instruction screen explained that the numbers on the SRT box matched those displayed on the screen.

3) The third screen demonstrated that the numbers on the SRT box always remained in the same order, while the order of the numbers on the screen changed.

4) The fourth screen described the goals of typing the sequence correctly and as quickly as possible, specifically that they wanted to get faster each time they completed the trial.

5) The fifth screen explained how to type the sequence on the SRT box when it was displayed on the screen. The participants were given the opportunity to attempt to type in the sequence if they wished.

6) On the sixth screen an example of a display screen for a sequence was shown with instructions to rest their finger on the key indicated by a red box surrounding it on the screen.

7) On the seventh screen an example of a green, ready screen was shown.

8) On the eighth screen an explanation that when the green screen disappeared, the participant was to start typing the sequence they were just shown as quickly and accurately as possible was displayed.

9) On the ninth screen an explanation of the choice process was displayed for the self-regulation groups and an explanation of how the researcher will choose the order of trials was displayed for the yoked groups.

10) On the tenth screen the count-down of trials remaining displayed on this screen was also explained.

11) On the eleventh screen, the screen displaying feedback was shown and explained.

12) On the twelfth screen the participant was shown a screen reminding them that they wanted to go faster then the last time they did each trial over all the trials.